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ADVANCED DISPLAYS AND INTELLIGENT INTERFACES (ADII)

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14. ABSTRACT

Current Command and Control (C2) situations have necessitated not only the requirement for a larger, higher resolution display system, but also a propitious interactive solution that will enable warfighters to execute their mission critical tasks effectively. Key decisions are made utilizing massive amounts of information, which is not only dynamic, but originating from various sources. The Advanced Displays and Intelligent Interfaces (ADII) program designed, implemented, deployed, and transitioned several evolutionary versions of the Interactive DataWall (IDW). The IDW is a contiguous large display solution equipped with multiple methods for application interaction, and the ability to receive numerous sources of data in real time. Fostering a collaborative environment, the IDW architecture enables multiple users to engage simultaneously with the display via camera-tracked laser pointer interaction and through speaker-independent speech recognition.

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High-resolution displays, large-screen displays, tiled displays, human-computer interaction, laser pointer interaction

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Executive Summary

The undeniable importance of large high-definition displays accompanied by advanced techniques for effective human-computer interaction (HCI) that are suitable for Command and Control (C2) environments are paramount to the success of satisfying the Air Force's information management requirements. Airmen are constantly faced with making key decisions utilizing massive amounts of information, which is not only dynamic, but originating from multiple sources including various military applications, sensors, databases, live satellite input, and video feeds.

The Advanced Displays and Intelligent Interfaces (ADII) program objectives and accomplishments include the evaluation, exploitation, development, and advancement of display and vital man-machine interaction technologies. As a result the Interactive DataWall has emerged as an operational product that is and continues to be a proving ground for new concept development and experimentation in these technology areas.

Techniques have been developed that leverage commercial-off-the-shelf (COTS) display technology to provide high-resolution large-screen displays by effectively tiling multiple video projectors in a near seamless 3x1 matrix. Custom support structures have been designed and fabricated to provide a mechanism to precisely align the independent display components to create a composite high-resolution display.

Information can be displayed on the DataWall in number of ways that range from running local on the its central computer system, over the network from remote systems, or utilizing COTS video processing hardware with custom developed software. All provide different levels of performance in terms of display refresh and interactive control.

Wireless interaction is accomplished through speaker-independent speech recognition and an in-house developed laser pointer input device. Live video of the display surface is processed to determine the presence and specific position of a laser dot on the screen to allow operators to interact with the information displayed. The laser pointer interface provides a mouse-like mode of input for a very natural and unencumbered means of data manipulation.

The usability and portability for field deployments of the systems under development has been a key factor most recently. The decision maker's role must not to be impaired by the mechanics of utilizing the tools available, but one that will facilitate better information management and an improved situational awareness to fulfill his/her mission. A significant amount of research and development has been accomplished to package the Interactive DataWall into

one that is field deployable. It has evolved into a system with more simplified set-up procedures and a significantly reduced deployable footprint.

Several systems have been transitioned to sites outside the laboratory including to warfighters in theater operations. The feedback from real users has been an invaluable resource to steer the development of our interactive display systems.

Future research and development for the Interactive DataWall includes the integration of touch and gesture as additional modes of input. Also planned are improvements to the display structures to further improve usability in the field including automatic projector and camera alignment mechanisms.

1 Introduction

Solving the challenges facing the 21st century commander in dominating the information management battlefield heavily correlates with the assimilation, analysis and strong interaction with not only an extensive amount of data and information, but that which is also detailed, dynamic, variable in format, and originating from multiple channels and resources. The immense amount of information encompasses sources and elements such as terrain and geographic area representations, land route maps, database information, intelligence and surveillance collections, graph analysis, target modeling and simulation results. In addition, increased tempo, higher precision, and more complex data sources have increased the demand for tailored information and have increased emphasis on revolutionary information technologies. Paramount to the aggregation of information are the display system's accessibility and real time performance, especially in handling streaming video and audio inputs, and while running highly intensive graphic 2D and 3D renditions. The ADII team recognizes the requirements and the importance of addressing the interdependent and intense issues challenging today's decision makers.

The development of a massive, high resolution tiled display has the ability to augment situational awareness for an entire C2 audience. The uniqueness of the Interactive DataWall (IDW) is the push to actively foster collaboration and participation among a collection of decision makers. Multiple users can simultaneously interact with the display, including those in co-located environments. Additionally enhancive are the multiple methods available to operators and decision makers alike for unencumbered control of the display workspace, via camera-tracked laser pointers, and wireless speech interaction.

Management of display development by the ADII team extends beyond the demands associated with massive, high resolution display systems and enhancing software functionality. Equal consideration is given to the conditions and logistics associated with utilizing this display technology. Military exercises and operations require integrated systems and software that need to be robust and functionally easy to setup. Moreover, such systems must be capable of withstanding extreme external elements and environmental restrictions while faced with the sometimes limited resources available to the warfighter. In essence, an ideal display system would be as cognitively and visually effective as it is physically capable. In addition, it would provide a large interactive workspace, be flexible during transportation and deployment, and have minimal footprint.

2 Interactive DataWall

2.1 Rationale

A tiled display is a matrix of multiple display devices such as Liquid Crystal Displays (LCDs), Cathode Ray Tube (CRT) monitors, plasma screens, or video projectors positioned next to each other, to create a single continuous image. The approach of using a large tiled display such as the Interactive DataWall (IDW) has evident advantages in enabling mission planning in today's battlefield. Primarily, a large tiled display offers more available workspace for viewing data and information. In critical C2 situations, enabling comparisons and relationships across different applications is critical to decision-making. Moreover, a larger tiled display is accompanied by an increase in image resolution, which leads to better image scalability. Higher levels of detail are available to the commander improving the viewing clarity and ability to manage applications. This is especially true for those requiring high performance such as graphical maps and high resolution satellite imagery. A large tiled display comprising of high-resolution devices provide the avenue for exposing deeper levels of imagery pertinent in analyzing and assessing essential details in visualized data. Furthermore, larger displays enable more effective collaboration within a localized working environment. Tasks where missions are planned and discussed necessitate information that is effortlessly shared with an entire audience.

2.2 Challenges

Attaining a considerably expanded display area is bounded by several fundamental technology challenges. The goal is to compose a perceptually whole viewable area utilizing a collection of individual display devices. Instrumental to constructing this single near-seamless display workspace includes optimally weighing choices for the components to minimize the disparity among tiles, both physical and image-related.

Approaches for both precise manual and automatic alignment for projection-based display systems are available to greatly reduce the visibility of seams and gaps between image tiles, but each with its own limitations and trade-offs. Color and brightness variations across projected images within tiled displays can also cause an inhomogeneous appearance to the imagery. What has to be considered in implementing solutions to these problems is what is acceptable in terms of image distortion, ease of adjustments, and the constraints imposed by operational environment conditions.

The creation of a large display space also introduces new challenges for effectively managing and interacting with the information displayed. Conventional input devices designed for desktop use are limiting and often cumbersome to use in large-screen environments.

The Interactive DataWall system architecture was designed cognizant of technology limitations and advantages to integrate the most optimal choices for display devices, screen materials, computer systems, video processing hardware, projector support and alignment systems, display software, and interactive techniques. All are essential to create an optimal display system devised for today's decision maker.

2.3 System Architecture

The Interactive DataWall (IDW) consists of three LCD-based video projectors, each with a resolution of 1280 x 1024 pixels. They're mounted in a horizontal configuration projecting onto a permanently installed 12′ x 3¼′ display screen resulting in a near-seamless single image. The current configuration has a total display resolution of approximately 3.9 million pixels (3840 x 1024) over the display area (Figure 1).

The IDW leverages vital COTS software and hardware components to drive its multi-screen extended desktop. All instances of the IDW through its evolution have been driven by a single central computer system configured with either multiple graphics cards or multi-output graphics cards. Each output provides a high-resolution source for each tile of the composite DataWall display. The creation of this meta-desktop allows windows to be repositioned and resized anywhere on the display. Projecting windows originating from multiple sources across these boundaries is of particular importance through the availability of the Microsoft® meta-desktop capability. Windows can also be maximized to fill the entire display. Many application windows can be run simultaneously on the DataWall computer with windows of current interest displayed in the foreground, positioned to the background or minimized for quick accessibility when needed.

Early IDW versions used high-end graphics workstations with special COTS software to create a very high-resolution workspace. During the latter iterations, Personal Computers (PCs) have been the primary DataWall platform due to a shift in cost and software support considerations. Several graphics card manufacturers capitalized on the meta-desktop approach and Microsoft® Windows widespread use by developing special drivers for earlier versions of Windows. In turn, Microsoft® recognized the benefit of this approach and provided built-in meta-desktop support since the release of Windows 2000. The utility of a meta-desktop to manage a user's information space is being recognized as users have begun to adopt the practice on their desktop PCs

using multiple monitors. The DataWall improves on the notion by increasing the scale for larger group viewing and providing a seamless, less fragmented display space.

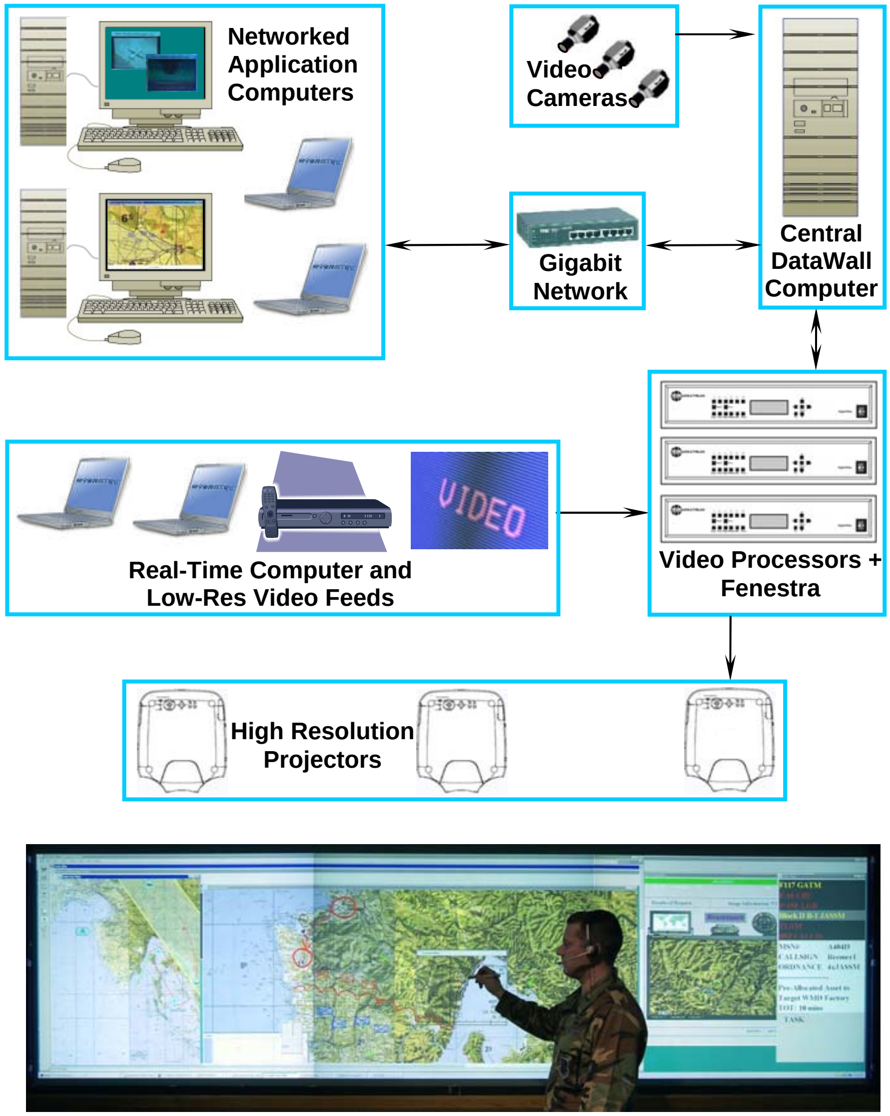


Figure 1 Interactive DataWall System Architecture

A vital part of the IDW is the ability not only to display PC driven applications, but to accept multiple inputs from various sources. The IDW architecture supports the ability to accept multiple live, dynamic video streams and displaying them in any of *n* x *m* configured tiles. Achievement of this feature is through the incorporation of three external video processors connected to the central DataWall PC system.

The extended display space enables the capability of a collaborative display environment. The latter iterations of DataWalls render the function for a number of decision makers to interact within the environment simultaneously via multiple cursors generated by a collection of networked application computers. Co-located application computers can also be controlled within the display space as well.

3 Capabilities

3.1 Displaying Information

3.1.1 Running Local on DataWall Computer

One method for displaying information on the DataWall is to have the application software installed and run on the central DataWall computer system. Running applications locally benefits from the ability to manipulate the applications with a variety of wireless input devices available. This is an important distinction between the centralized DataWall computer approach and the more commonly used video switching hardware approach. Even if only conventional keyboards and mice are utilized, the operators have control over the applications being displayed rather than the display serving only as a summary device.

This approach also benefits applications requiring optimal processing power and frequent refreshes to run efficiently such as graphics intensive visualizations. All IDW central computer systems have been customized with the latest state-of-the-art components during development. Though highly favorable for typical install- and run-programs, a fair proportion of Command and Control scenarios may determine the described resident approach as not necessarily the most practical. In many cases it is more efficient to run and display applications from remote computers because of software installation restrictions, and practical limits of any computer's processing power to run multiple applications simultaneously.

3.1.2 Network-Based Control Software

Developed with the University of Alabama, through a program entitled, "Enhanced Interactive DataWall for Collaboration and Data Fusion", collaborative software enables external systems reachable by existing network connectivity to be displayed. The software utilizes a VNC-based (Virtual Network Computing) framework and modified calls to allow applications running though this procedure to be manipulated simultaneously on the DataWall. Multiple cursors operating at the same time are available for users to work simultaneously across different

applications. Local application computers can push information to the DataWall directly utilizing a local network hub offering fast refreshes for the sources being displayed on the DataWall workspace. If global high-bandwidth network connectivity is available, or applications are required to be displayed that are more remotely located, they can also be displayed utilizing the same software. For this approach, network bandwidth and availability is the primary limiting factor for sending and receiving data.

3.1.3 Client-Server Coupling

Another alternative is a client-server based arrangement. The program with much lower overhead client software can run on the DataWall computer while the server runs elsewhere on the network. This is a very efficient means of displaying on the DataWall screen, but it requires predisposed client-server software.

3.1.4 Fenestra

A proportion of military collaboration involves sources that originate from external devices such as laptops and video devices that provide both recorded and live video feeds that need to be displayed in real-time. A display that fails to refresh at a comparable rate of the original source is uncomfortable to view and fails to meet the real-time requirement for mission critical data display. The DataWall system also incorporates a system called Fenestra (which means windows in Latin) that leverages COTS video overlay hardware with custom in-house developed windowing software to display live high-resolution computer video and low-resolution NTSC (National Television System Committee) video sources. It provides a means to manage external video sources within any tiled high-resolution display in real time, unimpaired by refresh latency characteristic of network-based approaches with slow connectivity. In addition to the ability to display multiple external sources in real-time it also has the advantages of not requiring network connectivity nor previous installation of additional software. The video windows can be scaled and oriented anywhere on the display screen, together with other DataWall controller tools. If network bandwidth is unavailable and conditions do not permit installing and running applications on the DataWall PC, it is an optimal alternative.

3.1.4.1 RGB Spectrum SuperView™ Hardware Description

A critical component of the Fenestra architecture is the SuperView™ 3000RT from RGB Spectrum. It is a COTS video processing system that can be configured to display up to twelve real-time video and computer signals on a single high resolution screen. Sources appear as borderless windows on the display space. It accepts NTSC/PAL composite video, Y/C (S-Video), and

component YUV signals from cameras, tape recorders, videodisc or teleconferencing systems, and high line rate video signals from computers, FLIRs, medical imagers, and radar with resolutions up to 1600 x 1200 pixels. Each input can be positioned, scaled to any size, overlaid with computer graphics or overlapped with other signals. In addition, the user can pan and zoom within each image. Control for manipulation of these windows is through the manufacturer's software package via RS-232 serial commands, or through an optional front control panel.

3.1.4.1.1 Advantages

Real-Time Performance – Compared to other methods of displaying external sources, the SuperView™ hardware can display high-quality, real-time video information and graphics on a large screen display without significant processing impact. The rationale for the remarkable performance is all video processing is segregated, and the SuperView™ serves as a pass-through device. Although the availability and popularity of TV tuner cards are more widespread and could be construed as an alternative, integrated cards suffer from the limitations of utilizing shared processing resources with the primary system. The notion of isolating all video processing into a separate system provides optimal tasking of delivering real-time information, videos, and images at a comfortable speed, void of noticeable lag during operator use. It also provides the capability to display high-resolution computer signal that a traditional TV tuner cannot support.

Dynamic Background – Compared to other video processing systems, the SuperView™ is capable of overlaying the primary computer system's background as a separate input. Additional sources are secondary overlays to the desktop. The setup enables the use of the primary system's resources, such as installed applications and saved files to be launched together with live video windows from external sources. Commonly in similar systems, the background is a static image, and only external video windows can be displayed, thus limiting the primary function of just being able to view multiple input sources.

3.1.4.1.2 Disadvantages

Although performance for rendering intensive graphics and videos is effectively satisfied by the SuperView™, there are limitations to its design.

Single Display Use – Although multiple sources can be projected for viewing and manipulation, the machine's design primarily caters to outputting to a single display device. In common C2 environments, large tiled displays such as the DataWall are utilized to display and manage the information. Restricting the live windows to one section of the screen out of *n* image tiles available is cumbersome and limiting to the operator, or the group of decision-makers who may wish to place windows, and manage the entire viewable space during

presentations and discussions. A version of the software is available for limited 2-tile window movement, however testing of the software during demonstrations revealed reliability issues, and a complicated user interface.

Interface Complexity – The manufacturer's accompanying software for display management imposes a high learning curve to use effectively. Considerable background knowledge is required in video processing procedures such as host and input timing parameters, and other computer and video domain-specific adjustments. For C2 environments, the task of the decision-maker or group of decision-makers is to utilize the videos and input resources to make determinate and knowledgeable decisions, and not to be impaired with the process of using the technology (Figure 2).

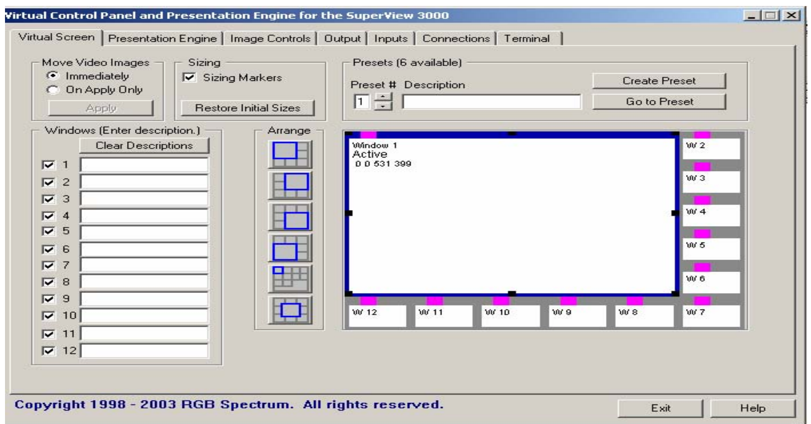


Figure 2 Manufacturer's Virtual Screen Panel

Indirect Window Interaction – As mentioned earlier, live video and computer inputs can be displayed via two methods. One is through the manufacturer's supplied software interface, and the other is through the front panel, an additional cost option provided in some SuperView™ models. The pitfall behind this implementation stems from the unnatural way of managing multiple windows. Both methods require the operator to cope and interact with source manipulation tools indirectly, and to map results against the display. As an example, to resize or move a particular window, sequenced steps from a multiple layered menu need to be traversed in order to push the correct parameter button.

If the method is through the Virtual Screen Panel, live window interaction is collateral. Users rely on feedback to verify movement within the white area by mapping events to the actual display work space. The Virtual Screen panel uses this map and verifies technique for moving and resizing windows, instead of a direct approach of managing windows on the display itself.

Timing Adjustments – The SuperView™ framework relies on the concepts of ordering overlays. Although the system technically detects the timing parameters

of each overlay, more often than not, further adjustments for accurate calibration are necessary. The background overlay, usually the primary computer's desktop, needs to be adjusted to map the display device's coordinate system. Tiled displays pose an added degree of complication since the calibration is performed *n* times, where *n* is the number of display devices. Similarly, input sources displayed as windows are treated as a second layer of overlays, and require procedures for calibration as well. The method for interacting with the display for acquiring correct timings demand additional operator learning, compounded by the interface complexities mentioned previously.

3.1.4.2 Video Overlay Requirements for DataWall Integration

The primary objective was to provide operators with the ability to effectively display high quality, real-time computer and low-resolution video from external sources onto the DataWall. The COTS video overlay approach discussed previously needed to be enhanced for tiled display systems and a needed a simplified user interface.

The original DataWall arrangement simply piped each of three SuperView™ outputs to one of three projectors comprising the DataWall. The SuperView's™ design limited viewing and managing windows within the perimeter of an image tile, corresponding to a single display device (Figure 3). A significant challenge was extending the wall control functionalities across a tiled display, such as the DataWall.

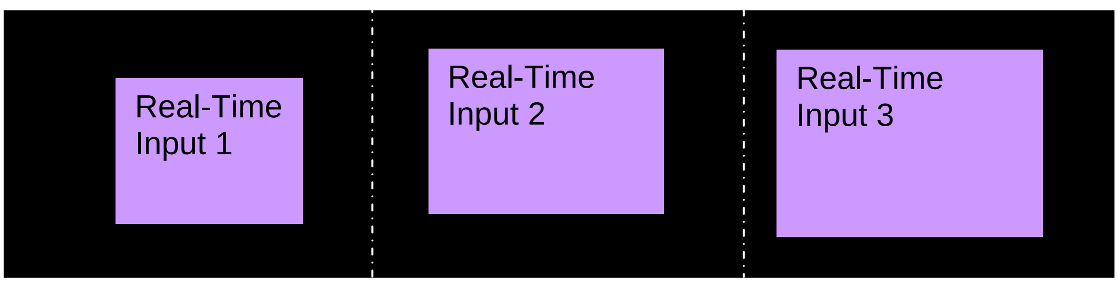


Figure 3 Original Video Window Configuration

User interaction for window management also needed to be direct and transparent. Complications regarding the hardware setup and the complexities of the SuperView™ operations needed to be hidden from the user. The most intuitive form for managing input interaction necessitated placing a windowing frame, around each displayed video source for direct manipulation. This would give the look and feel of any other application window to which traditional computer users have become accustomed (Figure 4).

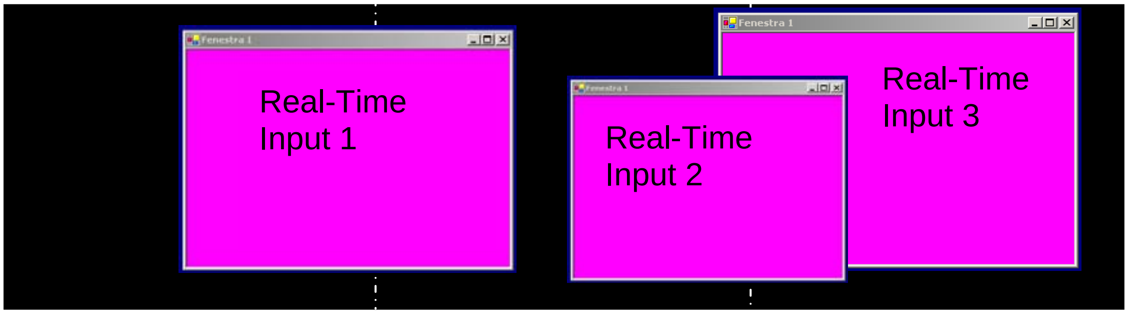


Figure 4 Video Window Configuration Enhancements

3.1.4.3 Architectural Design

Achieving fluid manipulation of live data windows across the DataWall display includes the following elements:

- The Fenestra application which provides transparent management of video windows
- An array of SuperView™ 3000 systems equal to the number of display devices
- The primary DataWall PC for communicating and exchanging RS-232 commands with the multiple SuperView™ systems
- Desired external video sources to be displayed in real time (can include computer and low-res video types such as laptops, video cameras, DVD players and TV tuner signals)
- Distribution amplifier for each video source to broadcast the same signal to each screen

The initial approach of displaying sources on a single large display device was be to map and attach each SuperView™ system to a single display device directly. Although the overall display appears tiled, the manipulation is restricted to the corresponding display device. The implementation for allowing Fenestra involves daisy-chaining each video processor box and program RS-232 commands for upstream and downstream communication via the primary DataWall PC driving the display. In the case of the DataWall, three SuperViews™ were utilized correlating to a three projector DataWall design (Figure 5).

The three video outputs from the DataWall PC are each connected to the background input channel of a SuperView™, and subsequently to each display device. Unlike other controllers whose primary purpose involves presenting multiple computer and video inputs, the organization provides the familiarity and

the use of resources, such as running applications, and opening files resident on the DataWall PC.

The current implementation allows up to four external sources for window manipulation on the DataWall PC. Each external video source is connected to a distribution amplifier, so that it may be input to each SuperView™ unit. The rationale behind this approach is to allow each complete input signal to be distributed across all SuperViews™ in order to be displayed anywhere on the tiled display. Depending on the desired location for displaying the information, segments of the window are matched with the appropriate coordinates to simulate the appearance of seamless window movement across all projected areas.

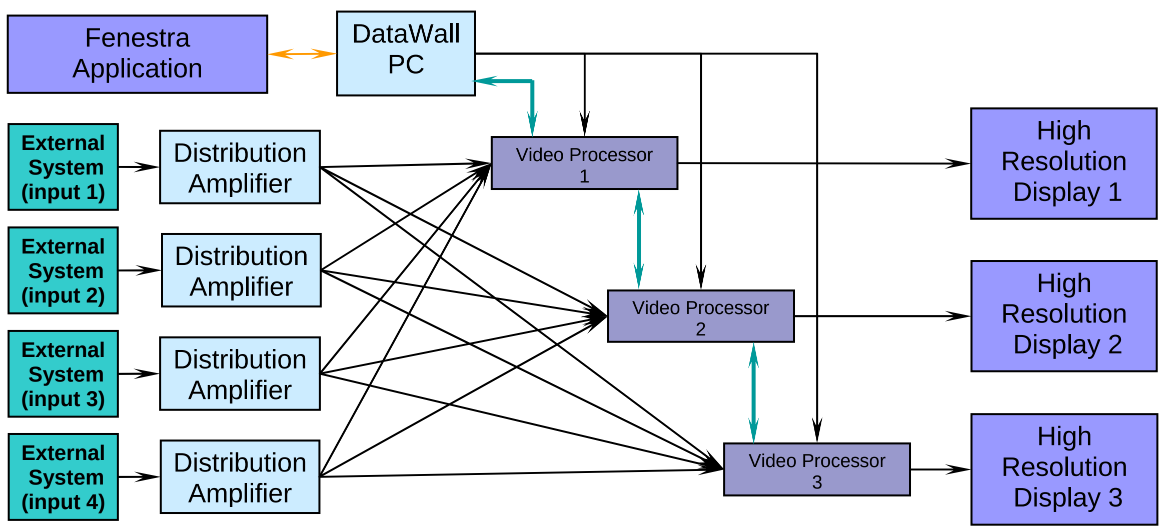


Figure 5 Fenestra Architecture

For hiding and explicitly allowing only the desired input overlay (such as the video and computer videos) to pass through the background overlay, a technique called chromakeying is utilized. An uncommonly used color, such as bright fuchsia has been chosen for the current implementation. Only against fuchsia-filled regions in the background overlay are computer and video inputs programmed to appear. The rationale behind using an off color for chromakeying lies on limiting the probability of allowing any artifact with the same hue to bleed unintentionally. This artifact is akin to weather forecasters who have accidental reflected weather maps on parts of their clothing corresponding to the same chromakey.

Each fuchsia colored window dragged across the screen has a corresponding input source commanded to intentionally bleed through this window, and thus appear to be contained inside a perimeter. The most current version of Fenestra

leverages on the same familiarity and look-and-feel as any standard Microsoft® Window.

The Fenestra application allows all components to work synchronously, and conducts all resources to achieve the required wall controller management tools. All source code is based on the .NET framework utilizing C#. Numerous languages and packages were investigated and evaluated to achieve the enhancement.

3.1.4.4 User's View

A key feature of Fenestra's design is hiding the complexities associated with effective video window management. From the user's point of view, a simplified process is all that is necessary to interact with windows. Connecting any computer or video device, launching the Fenestra software, and simply selecting any of the external sources to be visible comprise the steps in displaying any live window on a tiled display. Communication between all the components is performed automatically. The abstractions are hidden, and the user needs to only run the program.

From the user's perspective, windows are *moved seamlessly* across display tiles without any notion of the background architecture, incorporated techniques, and complexity of timing parameters and layers overlays. All window inputs can be scaled, minimized, maximized and dragged as intuitively as any standard Window and present live video and computer signals in real time (Figure 6).

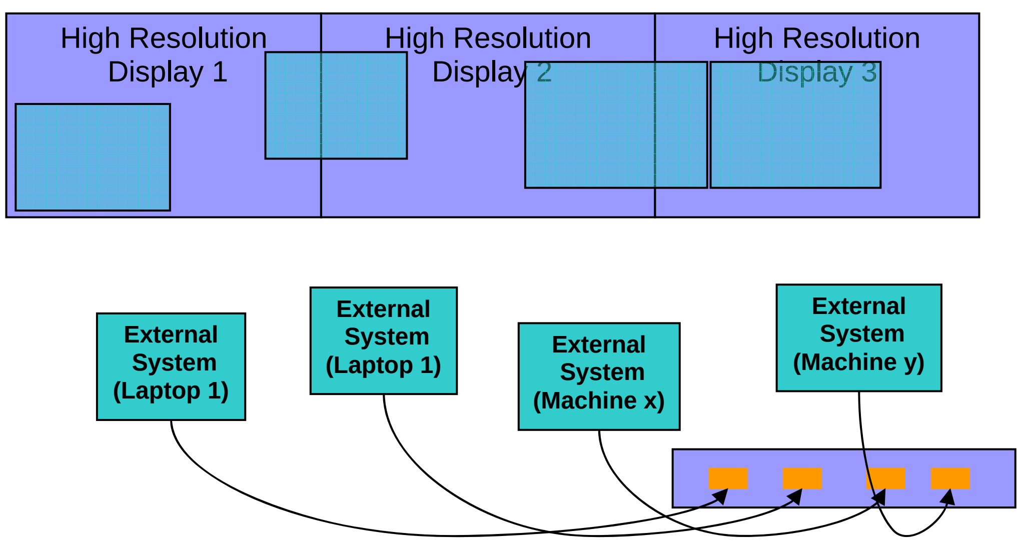


Figure 6 Fenestra User's Perspective

3.1.4.5 Fenestra User Interface Description

As discussed earlier, Fenestra's interface compared to the SuperView™ manufacturer's software is significantly more user-friendly and transparent (Figure 7). In addition, window manipulation is performed directly on the video and computer input across tiles, and not on the limited real estate of the video window controller interface.

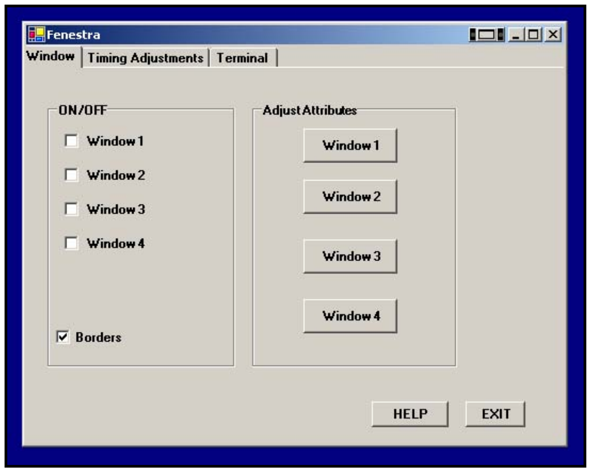


Figure 7 Fenestra Interface

3.1.4.6 Functions

- Direct Window Management (Figure 8)
    - The primary function of Fenestra is to enable direct manipulation of external sources as intuitively as possible. Each input is represented as a standard Microsoft® Window that can be dragged, minimized, maximized, resized and dragged anywhere across all tiles.

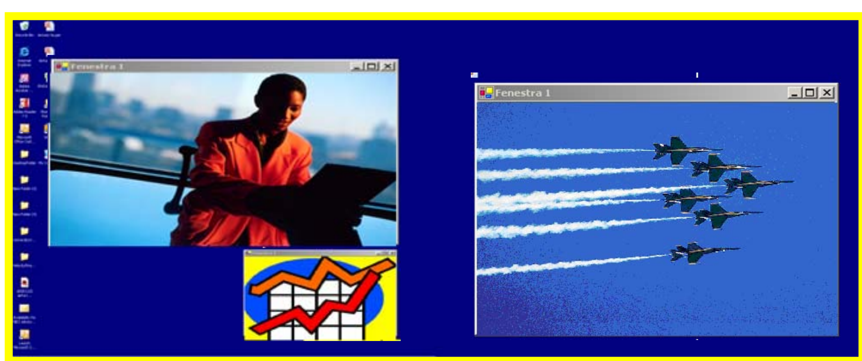


Figure 8 Fenestra Window Management

- Real-Time Performance of Computer and Video Inputs
    - o Display and removal of external computers or video sources on a high resolution display is easily achieved by selecting the appropriate input.
    - o External sources to be displayed are hot-swappable. Any external input can be displayed without restarting the program.

- Bordered and Borderless Modes (Figure 9)
    - o The addition and removal of external sources' borders create borderless portals that still maintain the ability to be resizable and movable across tiles. The objective of this feature was to accommodate multi-headed machines to be tiled and manipulated seamlessly within the large tiled display.

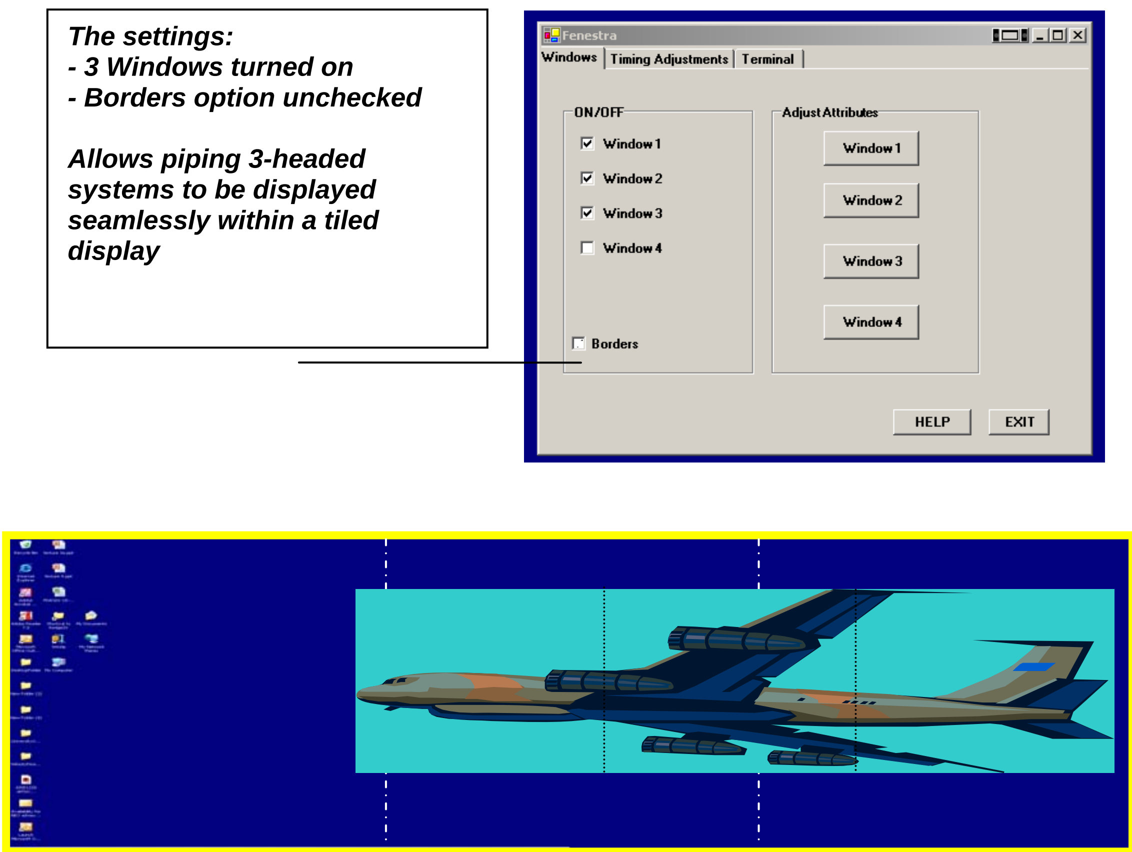


Figure 9 Borderless Window Mode

- Simplified Visual and Interactive Timing Adjustments (Figure 10)
    - The Fenestra occludes the numerical complexities and technical jargon involved in the series and layers of overlays to achieve generating the most accurate timing parameters for displaying external sources within a tiled display environment. The Timing Adjustment panel eases configuring the timings of each of the tiles within the background display (desktop), and the external computers and video sources connected to the SuperViews™.

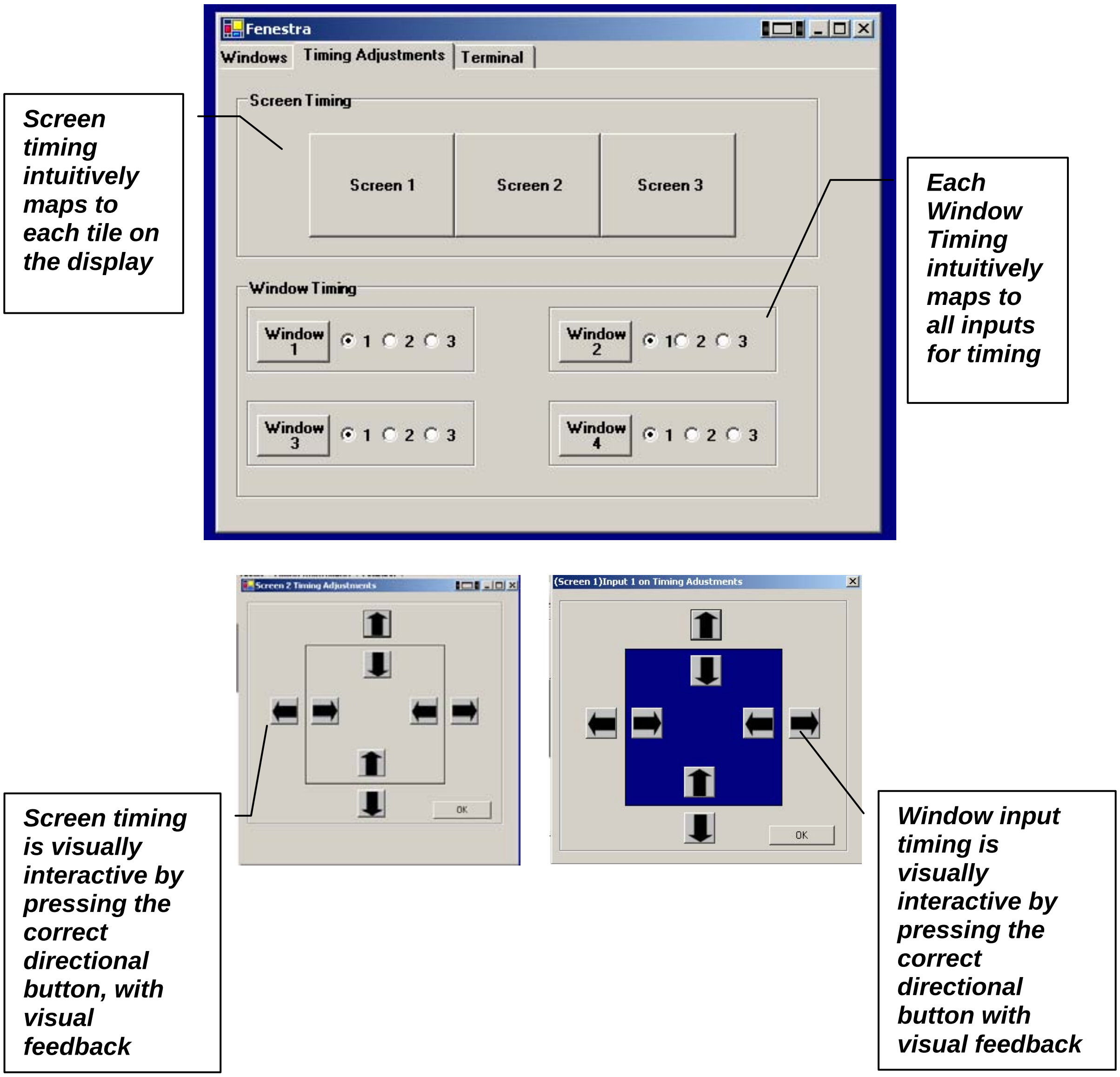


Figure 10 Fenestra Timing Parameter Adjustments

- Accessible RS-232 Terminal (Figure 11)
    - For more advanced functions and commands to control the SuperViews™, and to cater to more experienced users, a RS-232 terminal was developed. The terminal also serves as a tool for troubleshooting the system, serving as an all-else fails interface to send commands manually to the SuperViews™.

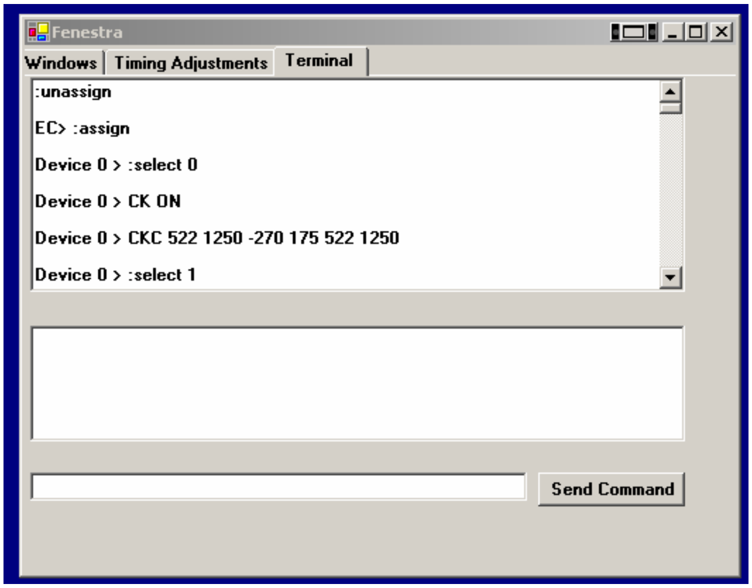


Figure 11 RS-232 Terminal Window

- Accessible Individual Preferences for Inputs (Figure 12)
    - Carefully chosen user preferences for each live window input can be configured. The panel is accessible by a right mouse button click on any of the windows, or by selecting the window number on the main menu. For better mapping of each window to each panel, title bars for each window bears the same window label. Changes can be performed from the window adjustment panel for identifying the proper signal source, desired aspect ratio of the signal, and preferred attributes to improve acuity.
    - Source Type adjustment – The source type which selects the type of incoming signal whether it's RGB or composite input.
    - Aspect Ratio adjustment – A selection of commonly standard video and computer aspect ratios are available, 4:3, 5:4, and 16:9 (HDTV resolution)
    - Acuity adjustments – A signal processed through the channels can appear differently from the source to the display destination. Catering to these conditions brought about the following commonly adjusted attributes: brightness, contrast, sharpness and hue.

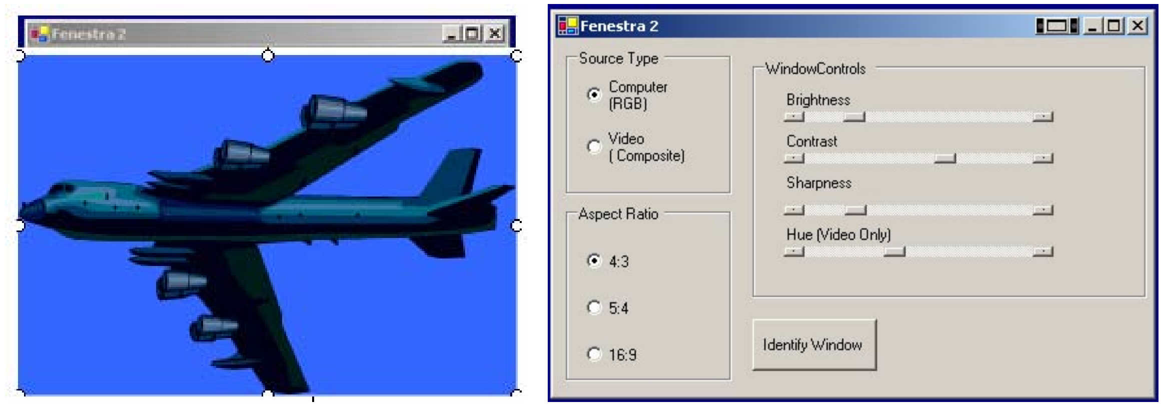


Figure 12 Video Window Adjustment Preferences

- Window Identify Confirmation (Figure 13)
  - o Large tiled displays in general require multiple windows which fills the work space area. Differentiating which window needs current adjustment, when multiple windows are open is beneficial.

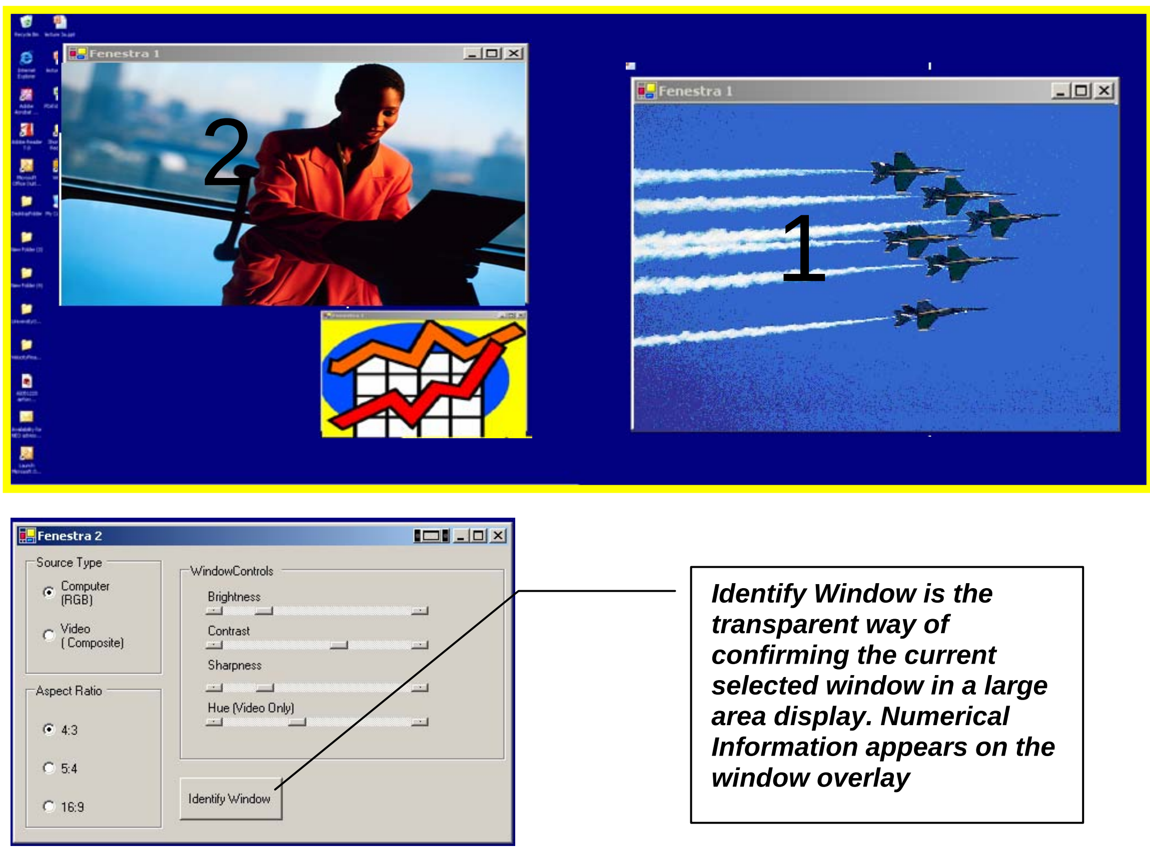


Figure 13 Identify Window

- Accessible and User Friendly Help File
    - Although the Fenestra interface is designed to be user-centric, a help file is also available to ensure proper setup, and procedure for operation. Information such as a general overview, a step-by-step general setup, necessary components, and an anticipated listing of question in the “how do I” section complete the help file. Most of the information on the help file are accompanied by guided graphics to further illustrate the necessary information to enable easy user operation

3.1.4.7 Testing and Evaluation

The challenges posed by the limitations of the SuperView™, and a need for effective integration into the DataWall system resulted in Fenestra. It is an architecture composed of both software and hardware components which fulfills the objective of providing an intuitive video windowing system to display multiple video and computer inputs on a tiled large-screen display. The implementation overcomes the restrictions of the SuperView™ while delivering a capability for operators to display, position, and scale multiple sources across a multi-headed Windows environment in real time. It has been designed to hide the complexities of the components and procedures from the user.

The Fenestra system was integrated in the Built-In DataWall. Positive feedback regarding the usability was received during these trials. Demonstrations include running intensive graphics and applications smoothly. It has provided an avenue for the DataWall to be a more widely used display resource for in-house staff and visitors to connect multiple laptops, and hot swap external inputs with ease to accomplish their tasks.

3.2 Wireless Interaction

3.2.1 Rationale

Most large high-resolution displays available in the present market are manufactured as passive systems. These systems typically only allow the user to view data, and provide little means for engagement and interaction. A factor that separates the DataWall and goes beyond its capability to provide an extensive global view of the information space, is its ability to function as an active and interactive work space and not merely as a summary device for information presentation.

Collaborators face the challenge of effectively managing massive amounts of data displayed on a large screen. The use of input devices such as conventional mice and keyboards is a cumbersome and limiting approach, which tethers user operations to a single location. The primary mode for managing and controlling information on the DataWall screen is through wireless input devices. The DataWall has capitalized on current speech recognition technology via wireless microphones and cordless telephones. Camera-tracked laser pointers offer a more natural and direct way of interacting with a large screen with mouse-like functionality. For users who would like to leverage familiar input devices, and yet would appreciate a more ubiquitous interaction, the DataWall also supports conventional mice and keyboards as alternatives.

3.2.2 Challenges

Operating wirelessly has clear advantages. However, for security reasons use of wireless devices is restricted within Department of Defense (DoD) installations and strictly forbidden in some cases including the use of COTS wireless keyboards. Any wireless device to be integrated needs to comply with security policies. Devices need to scale well for very large screens so that cursor movement is effortless and efficient. Devices also need to be accurate and intuitive to allow operators to use the display effectively. Intuitiveness is the most challenging by far.

The ADII program investigated the use of several wireless input devices with a focus on the development of a speech recognition system and a camera-tracked laser pointer which are discussed here.

3.2.3 Continuous Speech Recognition

3.2.3.1 Introduction

Incorporated in the earlier versions of the DataWall is commercially available voice-recognition software developed by NUANCE Communications. This program, together with a wireless microphone or a cordless telephone, enables a user to experience a fast, hands-free utility for display interaction. A user issues verbal commands, which the software captures, analyzes and executes by matching these instructions against a predefined grammar set. Such a voice-driven mode of input enables the user to perform common desktop operations such as manipulating windows, navigating menus, or executing customized instructions inherent in particular applications.

The NUANCE software is also speaker-independent. The software needs no training from a specific user to recognize instructions, and works well with accent

and voice variability. This proves to be an essential feature in collaborative environments like C2 situations where control over the display often needs to be switched from one user to another or multiple people frequently engaging with applications simultaneously.

The most current speech recognition system that was integrated into the DataWall environment used a novel approach by utilizing a Dialogic telephony card, a Skutch telephone line simulator, a cordless telephone, and the Nuance software. Using a cordless telephone in lieu of a cordless microphone had the advantage of freeing up the sound card for other duties that would otherwise be dedicated to the microphone. It also allows multiple telephones, thus multiple speakers to utilize the speech system simultaneously.

3.2.3.2 Testing and Results

Although utilizing continuous speech recognition presents many advantages and a variety of ways for automating tasks verbally, only a comparatively small amount of users would exercise this mode of interaction with the DataWall. The primary reason for its limited acceptance is due to the fair amount of learning and familiarity needed with the defined grammar set to become proficient with a voice-driven tool. In addition, some users have reported some uneasiness about wearing additional external gear such as a headset.

There is a learning curve to develop grammar sets that make this enhanced capability effective, but it is no steeper than learning any typical software package. In C2 situations where interaction with various applications is imperative, the use of voice recognition can be quite useful. It is common practice to have an operator responsible for the timely switching and coordination of applications being displayed. Voice recognition and interaction allows the presenter to take control of this task with simple utterances.

It has been very challenging to develop grammar sets that are generic enough to use with any application. Inevitably, to effectively voice-enable an application requires a custom grammar set for each application. It is for this reason speech input was all but been abandoned as a mode of interaction in the DataWall project. However, there is still interest in furthering its development when coupled to other input devices.

3.2.4 Laser Pointer Interaction

To provide a wireless mouse-like mode of input, a camera-tracked red laser pointer system was developed. Three video cameras are positioned behind the screen above each video projector. The live video from the three cameras is processed, and when a laser dot is detected on the screen, the cursor is

positioned at its location. In addition to cursor positioning, the system includes provisions for mouse button clicks to allow all the functionality of a conventional mouse including: dragging/dropping windows, resizing windows, and interacting with graphical user interface (GUI) widgets such as buttons and scroll bars. An important aspect of the laser pointer input device is that it is essentially application independent. However, since the Interactive DataWall runs on a PC platform under Microsoft® Windows, the application must be Windows compliant. The only other requirement is it must have a GUI.

Initial in-house development of the laser pointer interaction system pre-dates this in-house program, but contributed to the current system's evolution. The very first laser pointer tracking system consisted of three PCs equipped with video capture cards. The next-generation laser tracking system consisted of a custom hardware solution that was also developed prior to this in-house program. However, it was used extensively in several Interactive DataWall implementations developed under this program, the details of which are described here. The most current implementation of the laser pointer tracking system utilizes a frame grabber installed in the DataWall PC that also drives the display. What follows are descriptions of these various laser tracking subsystems.

3.2.4.1 Custom Hardware and Software

3.2.4.1.1 Technique and System Description

The very first in-house developed laser pointer tracking implementation that pre-dates this in-house program consisted of three PCs equipped with video capture cards. These computers provided a frame by frame screen capture for each video camera positioned behind the screen. The frames were analyzed via in-house developed software on the PCs and subsequently transmitted to the display computer for cursor positioning. Although quite effective, the process suffered several limitations. First, the system could not operate in real time. The approach required that the camera and computer complete a frame before analysis could begin. The delay penalty, therefore, was never less than the time required to complete a given frame. Second, both resolution and update rate were constrained by the processing power available at the time. A minimally acceptable 320 x 240 pixel image at 15 frames/second would fully consume the resources of a high-end PC at the time. Lastly, the cost/benefit ratio was difficult to justify as even a minimal system would cost several thousand dollars, and multiple PCs were required in these multi-camera implementations (i.e. one PC per video camera/display tile).

To address the limitations of the original PC/Video Capture Card implementation, the ADII team invented and patented (Pat. No. 6,377,242) specialized hardware

to track the laser pointer. It functioned in near real time, with readily expandable resolution, and at a small fraction of the cost.

In this implementation the three video cameras positioned behind the screen are equipped with red filters. The cameras' views of the screen are dark fields until the laser dot came into a camera's field of view. The live video from the three cameras is processed by the custom hardware and the data is subsequently sent to the DataWall computer for proper positioning of the cursor (Figure 14).

Figure 14 AFRL/IF's Custom Laser Pointer Tracking Subsystem Architecture

The device combines a microcontroller, video processing logic, a pair of counters, and real time control logic, which together track the pointer image. The process involves synchronizing the counters to follow the camera video. The cameras' views of the screen are dark fields until the laser dot comes into a camera's field of view. At the point in time when the camera "sees" the pointer, the counters will contain values representative of the pointer's position on the display surface. These values are then passed on to the display driver in near real time via serial cable to position the cursor.

In order to evaluate the effectiveness of the device, a side by side comparison between it and a 200MHz Pentium PC implementation was conducted. The exercise confirmed several significant advantages of the new system.

First, *speed*: The device can easily produce a detection each time the video scans the pointer while the original PC system could only consistently maintain a detection rate of 20-25% of the scan. Second, *timeliness*: The device begins to report a detection almost immediately after the video signal "sees" the pointer while the PC system must always complete a full frame before its analysis can

even begin. Third, *resolution*: In order to sustain a 10-15Hz-update rate, the PC version was limited to a resolution of 320 x 240 pixels. The device, is capable of 512 x 480 pixels, and can readily be increased to any practical video resolution without penalty. Fourth, and finally *cost*: The prototype single-camera device was assembled at a cost of less than $150 while the cost of the PC system was in excess of $2500. The single-camera tracking device or PC was required for each display tile. The device pictured above could process all three camera inputs, and several were built for a total cost of about $450 each.

3.2.4.1.2 Testing and Results

The custom laser tracking hardware implementation, first prototyped in 1998, was a significant improvement to its predecessor. It was not without its flaws however. Varying lighting conditions made calibration and continued operation of the laser tracking problematic particularly as the DataWall development ventured into portable systems where lighting was difficult to control. It was extremely difficult to get the camera iris adjusted properly to ensure detection of the laser dot on the screen while avoiding false detections of ambient light. The accuracy of the tracking was also less than optimal in that the cursor was always positioned several pixels from the actual laser dot on the screen. Experienced operators were able to adjust for the error, but novice users had great difficulty using the device. Even with its flaws it provided a novel, scalable, and the beginnings of a very intuitive method for wireless interaction on a large display. It was used extensively in several Interactive DataWall implementations until the development of the current laser tracking system that utilizes a COTS frame grabber was first prototyped during the Summer of 2002.

3.2.4.2 COTS Frame Grabber and Custom Software

3.2.4.2.1 Technique

The technique to track the laser pointer has come full circle back to a PC with a frame grabber approach. PC hardware advances and associated dramatic performance improvements over the last several years has also allowed the image processing to be executed by the central DataWall computer rather than an independent system. The most current implementation of the laser tracking system utilizes a commercially available high performance multi-channel frame grabber card to capture video feeds from three black and white cameras that are synchronized with a black burst generator (Figure 15). An individual camera captures all live images mapped to each display tile. Analog signals are saved and converted to a format intelligible for digital processing by software that utilizes a COTS imaging library. Custom software developed with the University of Alabama (contract no. FA8750-04-C-0067), together with the video frame input, executes a very reliable algorithm for accurately detecting the locations

and precise movements of processed laser dots and strokes within the display space to manifest effective laser pointer interaction.

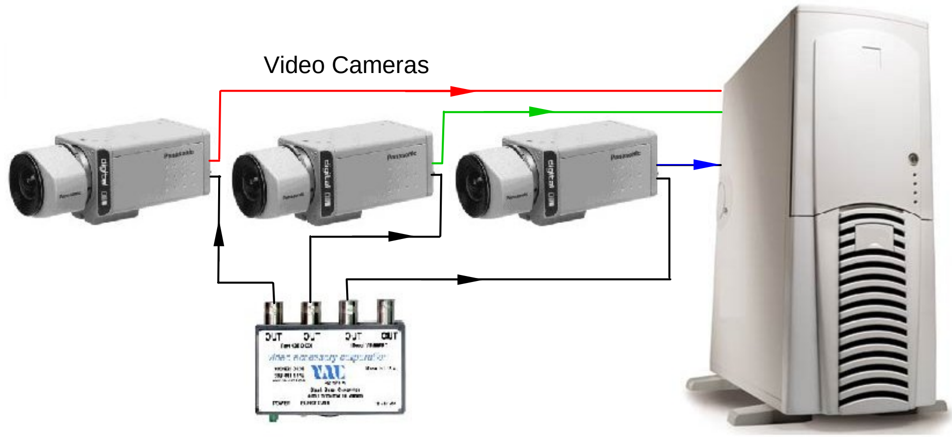


Figure 15 Frame Grabber Laser Pointer Tracking Subsystem Architecture

Initial versions of the camera-tracked laser pointer software were designed for single user interaction, thus it detected and supported only one cursor at a single point in time. The current algorithm enables multiple laser dots to be active, and multiple users to simultaneously interact with the DataWall display provided they each work on different applications.

Improvements for tracking multiple lasers dots have been applied as well. Procedures to allocate detection and simultaneous filtration of multiple laser dots have been implemented. The initial algorithm for detecting laser dots employed scanning line per line from top to bottom looking for the first pixel of a laser dot as the frames are captured by the camera. Predefined bounding boxes are utilized to search for multiple laser dots on the viewed camera frame. This approach may produce inaccurate results in scenarios where laser dots are in very close proximity of each other as a result of overlapped search boxes. Currently, a more refined approach creates bounding boxes when entire dots are identified first, preceding the recognition of the exact bounding box. In this manner, as long as two bounding boxes do not intersect, it easily distinguishes individual laser dots.

Improvements to the algorithm also include a divide-and-conquer screen masking technique for cameras to ignore any events outside the DataWall display area. The initial implementation examined each pixel within the camera image for inclusion or exclusion to the mask. The redesigned method considers only every four corners of the camera image plane. If all of the corners are within the mask, then the quadrant is included in the mask. This technique immensely accelerates the masking process as compared to validating each of the camera image's 307200 pixels. The applied masking process effectively prevented false

positives, and focuses the processed area to be within the proximity of the DataWall screen.

One of the limitations imposed by the Standard Microsoft® Windows OS is its dedicated single cursor framework. The enhanced customized software extends the VNC-based environment for allowing simultaneous multi-laser pointer interaction. A Regular VNC remote session allows any single PC (viewer) to have full operation of a networked system (server). The algorithm extends the remote session framework and incorporates the notion of *borrowing external cursors from multiple remote systems.* Running the customized software, at most accounts for x+1, the number of cursors simultaneously utilized. The number x maps to the count of external application systems (servers) that are connected via the network, and have running programs pushed to the DataWall (viewer) screen area for interaction.

Accommodating the specified multiple cursor platform, it follows that at most x+1 laser pointers can also be independently used on the display area at the same time. Implementation of the laser detection is through a stroke-based multiple cursor approach. Strokes are formed by detecting and examining each laser dot, verifying whether it falls on the category of the start of an active stroke, or the continuation of one. Active strokes have estimated next-positions based on the attributes of location and speed. Each dot is validated as a continuation of a stroke if it falls within the next-position tolerances of the available active strokes, or whether they signal the beginning of a new one. A stroke ends if no dots fall within the range of the estimated next-position of a stroke. Calculations are performed whether active strokes together with currently detected laser dots are determined to be inside or outside the pushed applications. Strokes that fall within these windowed applications have the ability to independently maneuver the cursor for that window. Although strokes per window can manifest multiple cursors within the DataWall area, only one stroke or cursor can claim ownership of an externally originating application at a single point in time.

The VNC framework has its limitations when conducted on a large tiled display. Core to its implementation requires transferring the entire screen of a remote computer to be operated as an application on the DataWall. The process of mapping each pixel of the remote screen to the DataWall is proportionally bounded by a combination of factors: the network bandwidth, the amount of pixels distributed along the network, and the amount of activity attributed to the application. Videos and highly intensive graphics are more prone to elicit sluggish refreshes while being run.

A driver-based approach is utilized to address refresh problems. The primary advantage of this technique is based on intercepting and transferring only commands for drawing instead of pixels from the originating remote system to the DataWall PC. Instead of a high volume mapping of remote to local pixels

being transferred to the display, the device driver approach requires only drawing commands to be transmitted from the source. The load of data required to move across the network is greatly diminished to produce remote applications running more fluidly and closer to the actual display time. Though the driver-based technique enhances the display rate and is almost fully functional it is still under development.

3.2.4.2.2 Camera Alignment and Calibration

Critical to accurate laser tracking is properly positioning the video cameras. The cameras must view the image area of its respective projector and little else. Slight overlap coverage among the cameras is acceptable because the laser pen tracking software will handle this. However, the goal is to maximize the use of each camera's sensor in order to provide the laser tracking software with the highest resolution image possible. The cameras are equipped with zoom lenses and mechanically adjustable mounts to accomplish this manually. Once the cameras have been aligned, a map must be established between the camera space and the display space. The process of establishing the map is referred to as automatic camera calibration. To establish the map, the system first takes a picture of a blank screen, then of a matrix of reference white dots on a black background. The centroids of those white dots on the camera image are identified. Finally a map between the centroids in the left side figure and those in the right side figure are established (Figure 16). To map a point in the camera space to a point in the display space, a bilinear interpolation algorithm is used [1].

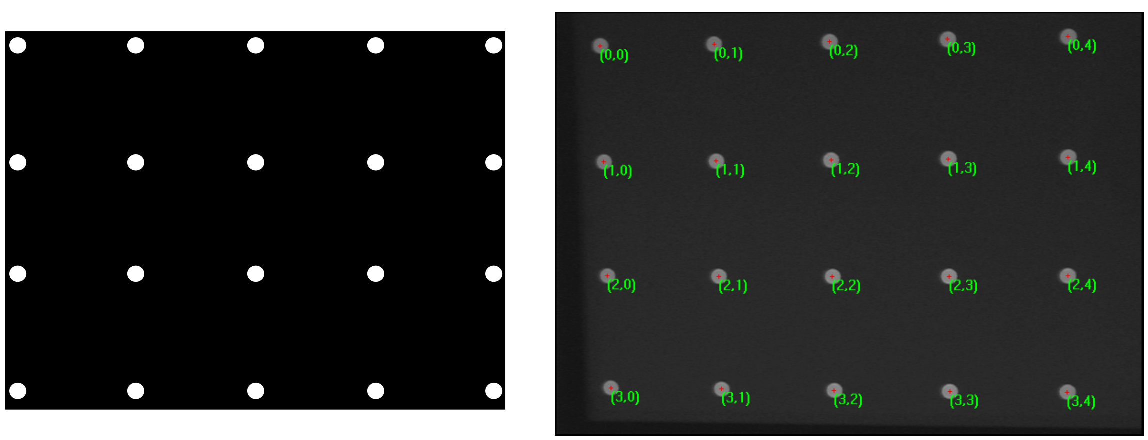


Figure 16 Mapping Between Camera Space and Display Space

Automatic camera calibration has many advantages. A map of size 4x5, 7x9, and 10x13 can be successfully created in just a matter of seconds. Early versions of the laser tracking calibration required a very tedious manual process of positioning the laser dot at each calibration point which would take several minutes even with a small number of points. It was also very difficult to accurately position the laser pointer at all the calibration points. With automatic calibration

even larger map sizes can be used to improve laser tracking accuracy with no impact on the calibration process that would otherwise be even more tedious using the manual process. Images taken by a camera with a wide angle lens have a severe radial distortion. To improve the accuracy of the mapping, more calibration points can be used and a piecewise bilinear interpolation with a larger number of pieces can be performed.

Enhancements to the camera calibration design focuses on safeguarding operations to assure precise laser pointer functionality. One of the tools added includes better automated software that calibrates cameras in proper order, and disables continuation of the process when anomalies are detected. Such anomalies can include unintended illumination of objects in the room or reflections on the screen that could be mistaken for calibration points; or incomplete camera capture of the display space due to incorrect camera positioning. Simple correction adjustments by the operator trigger the completion of the configuration. In addition, utilities are available for advanced users to select alternative arrangements, and other adaptive filtering processes.

3.2.4.2.3 Simulating Mouse Button Operations

To make a laser pointer work like a mouse, an interface was designed to perform mouse button operations such as click, double-click, drag, etc. A commercially available laser pointer has limited functions. Basically, it has one single button to turn the laser on and off. However, the laser pointer button operations map naturally to the mouse button operations. To simulate multiple mouse button operations a mouse resource window (MRW) is used.

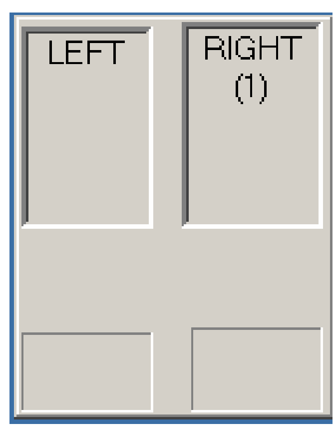


Figure 17 Mouse Resource Window Version 1.0

Version 1.0 of the MRW has 4 buttons (Figure 17). The top left one is used to simulate the left mouse button, and the top right one to simulate the right mouse button. If the left button mode is selected, the laser button will simulate the left mouse button: a push operation on the laser pointer button will generate a left mouse button down event, and a release operation on the laser pointer will send a left mouse button up event. In the same principle, if the right button mode is selected, the laser button will simulate the right mouse button. In principle, a left mouse button click operation can be performed by pushing and releasing the laser pointer button. However, the buttons of some commercially available laser pointers cannot react fast enough to simulate the click operation, and the laser dot will move when the button is pressed, especially if it is pressed at a distance. For this reason, two more buttons were added to the MRW. The bottom-left button is used to simulate the

single click operation on the left mouse button, and the bottom-right button is to simulate the double click operation. When no button is selected in the MRW, the movement of the laser dot corresponds to the cursor movement in the display.

Mouse button operations are a sequence of mixed left button and right button operations. A laser pen can simulate any sequence of mouse button operations with the help of the MRW. However, it is inconvenient to switch back and forth between the main application window and the MRW. Any sequence of operations can be divided into several subsequences, each of which is dominated by operations of a single button. For example, a mouse button operation sequence can mainly consists of left mouse button operations preceded by a few right button operations for menu selection. To reduce the number of switches between the main application window and the MRW, a temporal mode in addition to the permanent mode was integrated. When the laser pointer clicks on the right side of a button in the MRW, one operation of that mouse button will be reserved. Multiple reservations can be made by clicking the right side of the button multiple times. When the laser pointer clicks on the left side of a button in the MRW, it sets up the permanent mode. Figure 16 illustrates the permanent left button mode with one right button operation reserved. The laser pointer will simulate one right button operation followed by left button operations until the mode changes. The sequence can be used to bring up a menu, make a selection, and then continue with left button operations.

The current implementation, version 2.0, provides the same indispensable mouse functions with a more clear representation of both available and currently selected functions (Figure 18). All MRW buttons are permanently labeled with text as to their function rather than when they're selected as in the previous version of the MRW. The color of a button is more intuitively shifted to indicate it has been selected.

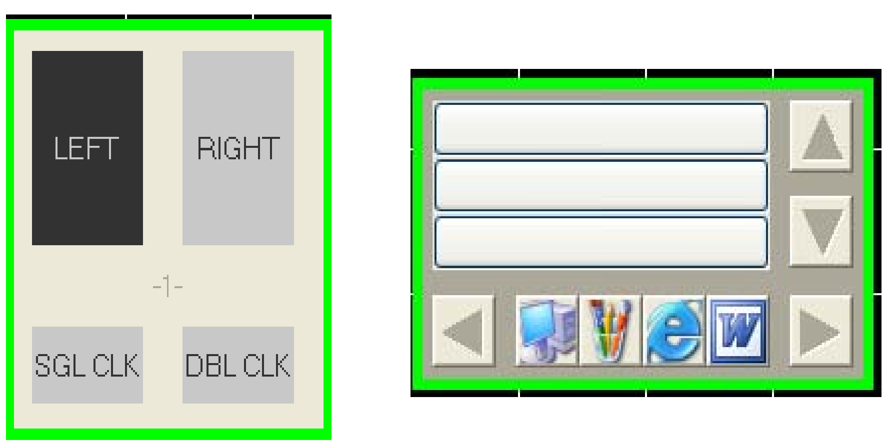


Figure 18 Current Mouse Resource Window Version 2.0 and Task Box

Additionally, a Task Box Interface accompanies each MRW on the display workspace. The Task Box grants participants, via the laser pointer, to scroll through the list of all open programs currently running on any remotely connected computer and to select a program to display on the DataWall screen. Moreover, available files, and commonly used programs can also be launched by selecting icons among those available on the scrollable horizontal collection.

Multiple remotely connected systems can display applications to the DataWall, thus allowing simultaneous laser pointer interaction. Each application shared has a matching mouse resource window and task box forming a set specific for that application. A distinct color is assigned to intuitively define and group the ownership of one set, and to provide a solid visual mapping during multiple concurrent laser pointers interacting on the display space (Figure 19).

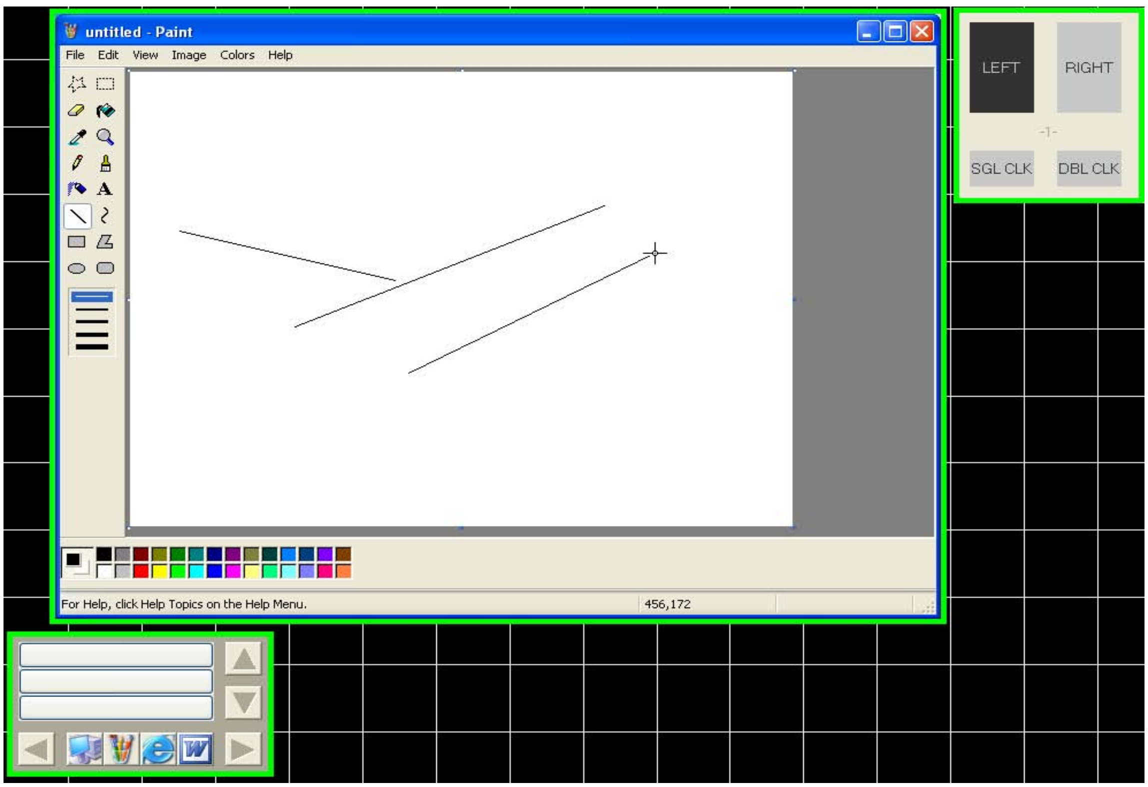


Figure 19 Color Feedback for Multiple Simultaneous Laser Pointer Interaction

4 Portable Interactive DataWalls

4.1 Rationale

As early as 1998 AFRL/IF recognized the utility of developing a field deployable version of the Interactive DataWall to get the display and HCI technology out of the laboratory and into the hands of potential users for evaluation to guide further research and development. Participating in various military exercises and conferences across the country would expose many more potential customers that might not otherwise have the opportunity to visit our laboratory. It could also provide a display system to showcase other AFRL/IF developed software that could benefit from the DataWall's display and HCI capabilities.

4.2 Challenges

Designing and implementing a large-screen display system based on Interactive DataWall technology that could be taken off site and used in a variety of environments was extremely challenging. A laboratory is a very controlled environment. The DataWall relied heavily on this for correct operation including controlled lighting conditions for the projection room to optimize projected images and the camera-based laser tracking. The unit had to be portable and deployment/set-up had to be very efficient to ensure timely operation. First attempts were designed around the assumption that the DataWall developers would support the deployment providing the necessary expertise to get the system operational. The ultimate goal was to develop a system that could be taken anywhere, required minimal tear-down/set-up, and tuned by inexperienced operators.

4.3 Deployable Interactive DataWall (DID) 1998-1999

The first deployable version of the Interactive DataWall was housed in an extensively modified Air Force S-530 A/G Standard Rigid Walled shelter, with its own Tactical Generator Set and Environmental Control Unit (Figure 20). It was completely self sufficient since it generated its own power and provided the necessary cooling or heating as the case may be for its electronic components. Three LCD-based projectors with short-throw lenses were used. In this configuration, each projector displayed 1024 x 768 pixels for a total display resolution of 3072 x 768 across a screen area 9' x 2¼'. At the time this was state-of-the-art in lightweight LCD-based projector technology. Although the system was developed during the 1998-1999 time period, before this in-house program

began it was the first implementation of a portable DataWall and is described here to understand the evolution of these portable systems.

Figure 20 Deployable Interactive DataWall

4.4 Portable Interactive DataWall (PIDW) 1999-2000

The Deployable Interactive DataWall proved to be a valuable asset for off-site demonstration support, but required a 15K forklift and flatbed truck to transport it. A Portable Interactive DataWall (PIDW) designed to be lightweight, easily disassembled, transported in light-duty trucks, and reassembled very quickly was then developed. It would be designed so that once assembled it could be very easily rolled to another location by two people. It would be PC-based and need to fit through a standard 3' doorway. Although a common practice for shortening the footprint of a rear projection display is to incorporate folded optics (i.e. mirrors), a conscious decision was made to avoid this. Mirrors add complexity to the alignment procedure, add weight, and are fragile if an optical quality glass is used.

A prototype system was completed May 2000 with a footprint of 9¼'W x 5'H x 2¼'D when folded and 9¼'W x 6¼'H x 4½'D when extended and operational. It was also a 3 x 1 LCD-based projector configuration. Each high-resolution projector displays 1280 x 1024 pixels for a total display resolution of 3840 x 1024 pixels across a screen area 9' x 2¼'. Projectors and cameras are a straight throw to the screen with wide-angle lenses to accommodate the extremely short-throw requirements. For deployment the lock pins on the hinged screen frame support arms are removed to fold the screen down in front of the unit. The screen is a flexible snap-on material than can also be easily removed and rolled up for deployment. The DataWall PC, audio amplifier, video overlay hardware, and video equipment such as DVD players or video cassette recorders are mounted in an integrated rack system.

4.5 Modular Portable Interactive DataWall (PIDW v2) 2000-2001

The prototype PIDW was deployed several times to support off site demonstrations, conferences, and military exercises that provided valuable insights into improvements. A common problem identified was the inability to get the PIDW into certain areas because of its length of 9'. Negotiating it into a room from a narrow corridor was impossible. The shipping container for the unit was also extremely large and heavy which still required a forklift for deployment, albeit smaller than what was required to deploy the DID.

The next version of the PIDW was designed to be modular and could be disassembled into sections to allow greater flexibility for set-up in tight spaces and to allow transport in smaller containers that would fit on a standard 463L cargo pallet; an important characteristic necessary for overseas deployment by military transport (Figure 21). Shock-mounts were added to the equipment rack to allow a majority of the equipment to remain in place when the system was transported. This significantly reduced the number of shipping containers and greatly simplified disassembly and reassembly because all connected cables could remain intact. Two prototypes were completed January 2001.

Another area that needed improvement was the projector mounts. Although they did provide 6 degrees of adjustment (x, y, z, roll, pitch, and yaw) to achieve image alignment, the lack of fine tune adjustment for x, z, and yaw made the process very tedious. It required manually sliding the projectors on slotted plates for each adjustment that were very difficult to move with the precision required. A new projector mount was designed that included a threaded adjuster that could be turned at small increments to reposition each axis more smoothly and precisely. A prototype mount was fabricated, but problems with machining the adjustment fittings to the necessary tolerances prevented the design from being integrated.

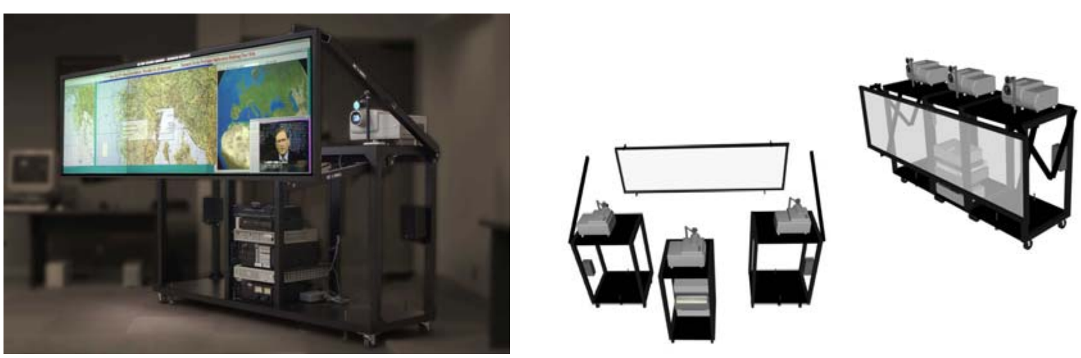


Figure 21 Modular Portable Interactive DataWall

4.6 *Collapsible Interactive DataWall (CIDW)*

4.6.1 CIDW Version 1 Prototype 2001-2002

The latest version of the DataWall under development takes portability to a new level. A primary objective throughout the portable DataWall development has been not only to provide a minimal operational footprint, but also a minimal transport footprint. Using commercially available reconfigurable T-slotted aluminum extrusions and fasteners, a collapsible frame with minimal disassembly was developed. It is designed to allow the entire frame to collapse such that the frame will occupy a much smaller footprint when folded for transport and fits in a single, more manageable container (Figure 22).

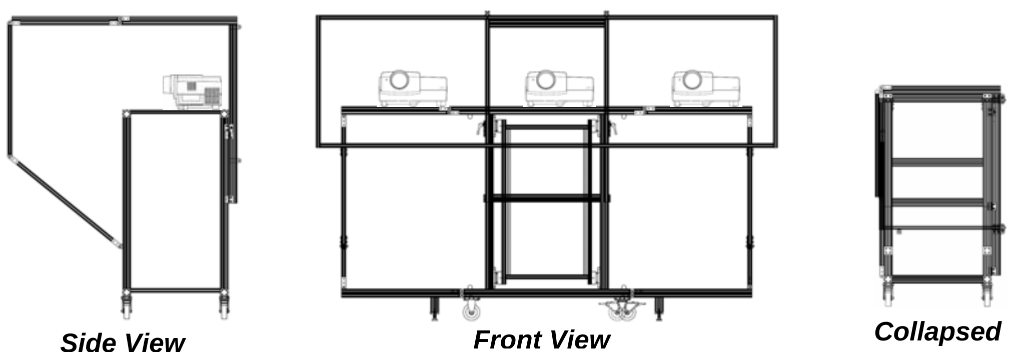


Figure 22 Collapsible Interactive DataWall Version 1

4.6.2 Advantages of Material

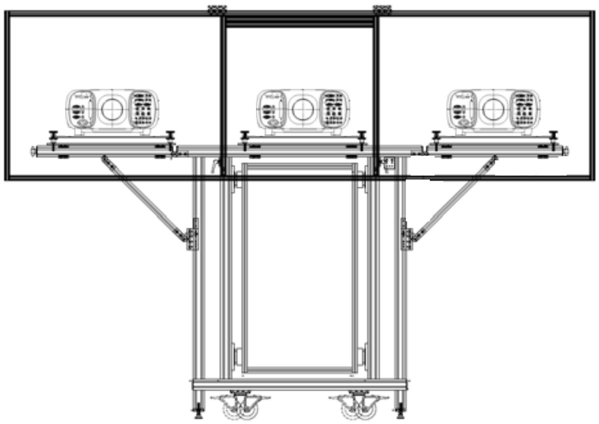
The 80/20 material has a number of advantages over conventional materials previously used in earlier version of the Portable Interactive DataWalls. Some of the accessories available include lockable sliding bearings that allow sections of the frame to collapse and extend rather than be disassembled and reassembled. This makes deployment and set-up effortless and requires no tools. Using the COTS material allows quick and efficient fabrication of the DataWall frames that have previously been custom fabricated with riveted tubular aluminum. It also simplifies design changes and can be modified easily. The material has been evaluated very favorably on the following criteria: cost, weight, ease of assembly, consistence of assembly on deployments, and structural rigidity. It is now the material of choice for all our current and ongoing display frame projects.

4.6.3 Prototype Design Issues

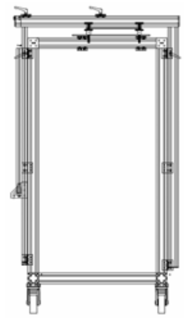
The first prototype completed July 2002 had a number of issues that were identified. For cost reasons the first design tried to keep the use of bearing systems for the folding parts to a minimum. The design relied heavily on hinges and lock pins to extend and collapse the frame. However, the lock pin mechanism had too much play in the connection and did not give the structural rigidity required. There were also issues with the upper horizontal screen supports from which the screen was suspended. The weight of the screen frame caused the support arms to sag because they were not adequately supported along their span. The original design also required removal and repositioning of certain support extrusions to collapse the unit. The goal was to keep assembly for deployments to a minimum.

4.6.4 CIDW Version 2 2002-2003

The next version of the frame was a significantly more simplified and elegant design that used nylon slide bearings at all collapsing points. The additional cost far outweighed the benefits they provide. Each folding/extending point can now be very securely locked into place in either position. The base of the unit when in operational mode is also much smaller. The projector platform now relies solely on the strength of the locked bearings rather than vertical support beams that previously connected the top and bottom sections of the frame. The upper screen support arms were redesigned to telescope rather than fold and additional vertical supports were added that corrected the sagging problem identified in the prototype's design. The screen frame was also redesigned to be more rigid by replacing the folding hinge mechanism with a sturdy butt joint that connects the left and right screen frame sections together. Although it now requires the screen frame to be disassembled into two pieces for deployment it is significantly more secure once assembled. Version 2 with the upgrades described was completed January 2003 (Figure 23).



Front View



Collapsed

Figure 23 Collapsible Interactive DataWall Version 2

As COTS projector technology improved new products were integrated into the system. To avoid a major redesign of the frame, investigation into a projector upgrade that had similar characteristics was conducted. Most critical were the projector footprint, resolution, and throw distance to image size ratio. The only choice available was a new product from NEC, model GT2150. It met all the requirements with the added benefits of being brighter and with a unique motorized vertical and horizontal lens shift capability. The lens shift provided an invaluable capability to electro-mechanically shift the images left-to-right and up-and-down, dramatically simplifying and improving the alignment procedure that previously had to be accomplished mechanically via the rudimentary projector mounts.

4.6.5 Projector Mount Redesign and Integration 2003-2004

Although the lens shift capability of the new projectors provided a much needed improvement to the alignment procedure it only provided adjustment for the x and y positions and did not provide the fine tune adjustment that was desired. A new 6 Degrees of Freedom (DOF) projector mount was developed that incorporated some elements from the previously unsuccessful design, but took advantage of the frame extrusion T-slots to provide a channel for sliding linear bearing mechanisms for the x (left/right) and z (forward/backward) adjustment. Each can be adjusted by a threaded rod and knob that can be turned for precise repositioning of the projector. The y position (height), pitch, and roll can be adjusted by a series of knobs positioned at each of the four corners of the projector mount. Yaw can be adjusted by rotating the top of the projector mount that pivots at a fixed position in the center (Figure 24).

The new projector mount was a substantial improvement and was able to take advantage of the 80/20 characteristics for a more smooth and precise positioning mechanism that was unsuccessfully attempted previously. Off the shelf parts were used without requiring precision machining of any components. The locking mechanism was also an improvement that requires no tools and does not affect the projector position when locked into place. Both were issues with the previous projector mounts. The new projector mount assembly design and integration were completed January 2004.

Figure 24 CIDW 6 DOF Projector Mount

4.6.6 Integrated Shipping Container Design and Integration 2004

To further improve portability of the CIDW system, a shipping container that was also more portable was developed. Custom fabricated containers made of plywood had been used previously and were very heavy and difficult to move. Containers for the Portable DataWalls have drastically decreased in size through it evolution but even in its now very compact form the CIDW alone is still very heavy, compounded with the weight of a still sizable wooden container.

Initial experiments to add casters and a ramp to the container, to roll the collapsed CIDW inside provided some benefit, but there was also the issue of storage space for the container when it was deployed. First attempts to design a container that could be disassembled for better storage were unsuccessful because it comprised its structural integrity. It was also still fabricated from heavy plywood which made disassembly and reassembly very difficult.

Manufacturers that offered custom containers made from lightweight plastic were contacted. One material that was identified had a unique laminated cellular construction that was claimed to be comparable in strength to ABS-clad plywood. It also offered the ability to construct a container of unconventional size that was not possible with molded plastic at a reasonable cost. After researching the types of containers these manufacturers provide, lead to a unique approach of integrating the container into the CIDW frame, rather than rolling it into an independent container. Using a clamshell container design the base of the container was fitted with casters. The casters on the CIDW were removed and the unit placed in the container base. When the CIDW is fully collapsed the clam shell sides are positioned on the base, clasped together and the base to fully contain the unit. The lightweight plastic is extremely easy to lift into place by a single person. The container was fabricated and integrated into the CIDW September 2004.

4.6.7 Touch Screen Collapsible Interactive DataWall 2004-2005

A frequent question from visitors to the ADII research facility and DataWall users is whether a touch screen interface could be integrated. Until recently there were many limitations to touch screen technology that made integration into the DataWall difficult and also compromised image quality. A common COTS approach is to use touch sensitive film that lays over the display surface. It is never a completely transparent material which subsequently degrades the image quality of the display. They were also not scalable to very large displays. Perimeter infrared sensors were also an early approach which lacked the accuracy and resolution needed, and like the touch sensitive films were also not very scalable. They were best suited for smaller flat panel displays.

COTS manufacturers have since developed touch screen technology using camera-based sensors. Although still marketed for smaller flat panel displays and single screen rear projection display systems, the approach has great potential for scalability to much larger multi-projector display systems.

Development of a touch screen capability for the CIDW is currently under development. Because of the extensive modifications required, a completely new CIDW was designed and fabricated for the touch screen research so that our current system would remain operational for demonstration support. Starting with the current design as a baseline a rigid screen is being integrated, and modifications were done to the frame to incorporate new projectors and accommodate the additional weight of the screen.

4.6.7.1 Rigid Screen Investigation

The CIDW was chosen as an experimental platform for investigating the feasibility of a touch screen. The first challenge was to integrate a rigid screen that was still portable and could be disassembled, but also rigid enough for touch interaction when assembled.

Three rigid screens each 36″W x 29″H that met the requirements for throw distance and best estimate for thickness were purchased. A perimeter screen frame to tile the three pieces together made of the same 80/20 material from which the CIDW frame was constructed was also purchased. The screen frame was also sectional for portability. A number of problems were immediately apparent during the initial testing phase. First and foremost, although the screen was ¼″ thick it was not rigid enough for the application. Because the screen material was only captured around the perimeter of the entire 3x1 tiled screen, the individual screen tiles flexed too much at the seams when touched. The screen was also a 2-element material that was difficult to keep tightly together with this type of screen frame. This also contributed to the flexing and introduced some ghosting to the projected images.

In light of this it was determined either a thicker or denser, more rigid, single element screen with a custom screen frame would be necessary. Discussions have started with a number of COTS screen designers and vendors to procure a screen that meets our specifications, but no design has been finalized.

4.6.7.2 Projector Identification

As projector technology improves COTS models are discontinued or replaced with models of slightly different specifications. Although the portable DataWalls have always been designed to allow hardware upgrades with minimal modifications they are still bound by projector footprint and throw distance.

Selection of COTS projectors that meet our requirements for footprint, resolution, throw distance to image size ratio, and power has been extremely limited.

The trend in projector technology has been away from the SXGA resolution of 1280 x 1024 pixels toward SXGA+ of 1400 x 1050 and high definition (HD) of 1920 x 1080. Although there is a desire to eventually use the HD format projector, model selection is very limited and currently geared toward the home theater market. These applications are typically front projection with throw distance to image size ratios greater than 1:1, designed for longer throw distances much greater than 3'. So, finding a model with a short throw lens option that accomplishes a throw ratio less than or equal to 1:1 for rear projection has been even more limited.

An SXGA+ DLP® projector was selected from Christie Digital, model Matrix 3000, based on availability and the closest in specifications to previous projectors used for the CIDW. They have the benefit of motorized horizontal and vertical lens shift similar to the projector they replace. They are also specifically designed for multi-projector applications with more consistent color and brightness.

4.6.7.3 CIDW Frame Redesign

The Christie Matrix 3000 projector's footprint and offset lens required some modifications to the CIDW integrated projector mounts. A slightly shorter throw ratio also required the screen to be mounted a few inches closer to the projectors.

The most significant change to the design was the screen support structure to accommodate the additional weight of the new rigid screen and screen frame that is estimated to weigh in excess of 100 lbs. The telescoping upper screen support arms were redesigned with an integrated metal rail bearing to replace the nylon bearing system in the previous design. The lower screen support arms were also redesigned with a similar telescoping rail bearing system to replace the simple locking pivot joints used previously. The vertical bearing system that raises and lowers the entire screen support assembly were also redesigned with a rail bearing system to replace the nylon bearings. In addition hydraulic pistons with a motorized pump raise and lower the screen assembly at the touch of a button that previously had to be lifted and lowered manually (Figure 25). The rail bearings are each rated for a dynamic load of 2810 lbs which far exceeds the entire screen assembly weight and should prove more than adequate for precise extension and retraction of the rigid screen. Maximum operating temperature is 175°F with an accuracy of 0.001″ of running parallelism. Although the rail bearing load capacity was overkill, they were the narrowest available rails that would mate directly to the extrusion and provide sufficient surface area for solid mounting.

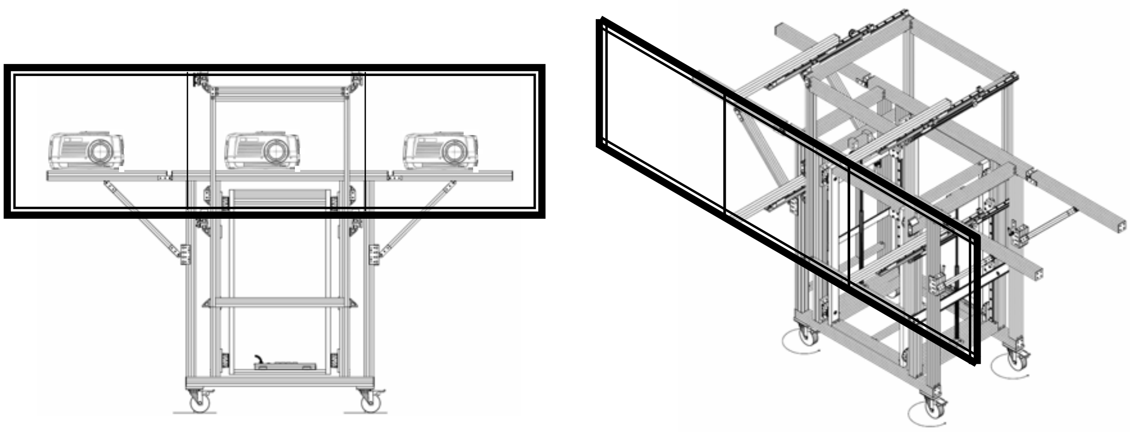


Figure 25 Touch Screen CIDW Design Concept

4.6.7.4 Touch Sensor System

The software and hardware that will accomplish the touch sensing will be contracted out to a commercial touch screen developer. It is anticipated that current off-the-shelf technology can be leveraged and scaled to a much larger tiled display than what is currently available.

4.6.8 CIDW Marketing

Although the CIDW continues to be improved the most current system is extremely well designed with an abundance of functionality not currently available commercially. Working with a local contractor a CIDW information packet was created in the event that if a potential customer was interested in acquiring one, a detailed description and pricing would be available. The contractor is poised to take over the production and support for any future systems sold.

5 Technology Transitions

The Interactive DataWall in its various stages of development provided several technology transition opportunities, particularly the portable versions. Several systems were transitioned off-site to environments that ranged from experimental facilities to operational theater. The details of these transitions including lessons learned and current status are discussed below.

5.1 51st Fighter Wing, Osan Air Base, Korea

A Portable Interactive DataWall (PIDW) was installed 26 November 2001 at the 51st Fighter Wing at Osan Air Base, Korea to support the Restoration of Operations (RestOps) Advanced Concept Technology Demonstration (ACTD) funded through the Defense Threat Reduction Agency (DTRA). RestOps simulates the recovery of operations from a chemical or biological attack. The PIDW was part of an effort to move the recovery center's command and control from one based on voice communications to one based on sharing of data electronically. Previously, field teams assessed battle damage, collected and analyzed potential contamination after an attack and then relayed the results via radios or in person to the Wing Operations Center (WOC). Staff at the WOC would utilize large maps with Plexiglas overlays and grease pencils to show the status of the base after the attack. RestOps provides an interactive C2 planning tool that automates the flow, analysis and display of information from the field to the WOC and, therefore, very effectively demonstrated the DataWall's ability to improve collaboration.

Although they did not have a need for a portable display that would be moved frequently, the PIDW’s minimal operational footprint and self-contained design were the characteristics most attractive to the RestOps system developers. Elaborate facility modifications such as a rear projection screen installation and projection room construction were unnecessary to integrate the display system into their facility. The system was assembled, loaded with software and was fully operational soon after delivery.

5.1.1 Lessons Learned

The PIDW proved very useful for the preliminary phase of RestOps particularly its minimal impact on the facility in which it was installed. It is important to point out that because RestOps is an application that would run immediately after an attack, personnel using it would be wearing fully encapsulating chemical warfare defense (CWD) gear. This early PIDW employed the wireless interactive capabilities available in today’s model. However, early implementation of the laser interaction was not very accurate and personnel had difficulty working with it because of the CWD. Speech recognition was also not a mode of interaction suitable for this type of application. Furthermore, even if the application utilizes hot keys that could make use of the speech recognition it would be nearly impossible because of the CWD mask that is worn.

Another area of concern for the developers and users of RestOps is the color balance and hot spots, which can be attributed to the inherent differences that exist from projector to projector even when they are the same model. Although RestOps is not a mapping application in its entirety, it relies on a map to show

the progress of field checks across an installation. The color imbalance and hot spotting could in some instances be a distraction to users.

Difficulty for inexperienced users to effectively align the projectors was realized well before RestOps, but had yet to be addressed. RestOps did reinforce the necessity to develop a more effective alignment mechanism.

Figure 26 RestOps DataWall at Osan AB Korea

5.1.2 Impact and Current Status

RestOps and use of the PIDW by other organizations has resulted in significant improvements to the data interaction as well as set-up and portability. For instance, the importance of improving the laser pointer interaction was realized. The summer of 2002, began the development of the laser pointer interaction software that utilized a COTS frame grabber. The result was far more accurate and more easily calibrated than its custom hardware predecessor. The goal is to allow any user to quickly calibrate the software and begin interacting with the data. In places like Osan AB where personnel rotate every 15 months, it's important to provide an interface which is intuitive.

COTS and university developed hardware and software are available to accomplish more seamless tiled images with more accurate color balance. However, because they use edge blending and image warping, a conscious decision was made not to implement them to preserve the full resolution of the display. Proper image alignment is still required even in instances where these techniques are implemented. Effort was focused on developing a more effective fine-tune alignment mechanism that was recently integrated into the most current CIDWs. Significant advancements in COTS projector technology over the last few years have seen drastic improvements in color and brightness consistency.

Although these improvements have solved some of the issues, there are still plans to implement some level of automatic color balance adjustment in future systems.

RestOps has transitioned into a larger situational awareness C2 tool for Commanders. Although it has not been approved for fielding, many instances of the application have been distributed throughout the military. Developers insist laser interaction is not an effective means of working with the data because it slows users down. The argument is that a majority of the users have grown up playing PC games and have mastered the use of the mouse, thus being able to navigate through the application at a faster rate than with the laser pointer. Collaboration with the developers to find an effective way to interact with the data will continue, especially when the application must run after an attack and personnel are wearing cumbersome CDW gear. The system remained operational until the next phase of the RestOps program which required a much larger display than this portable system provided. However, the Portable DataWall proved very useful for the preliminary phase and valuable insights from users were instrumental in its continuing evolution.

5.2 Army 10th Mountain Division, Fort Drum NY

The 10th Mountain Division is a light infantry unit dating back to World War II. Although it specializes in mountain fighting, the unit has evolved into one capable of fighting in any terrain. But as the name implies, it is light infantry with no heavy fighting vehicles. This in turn allows them to deploy quickly and tackle a wide variety of contingencies.

On 3 December 2001, AFRL/IF was contacted by the 10th Mountain Division regarding the immediate deployment of one of the AFRL Portable Interactive DataWalls (PIDWs) in support of the war on terrorism. Personnel of the 10th Mountain Division were familiar with the PIDW's capabilities as a result of participation in a number of field tests performed jointly at Ft. Drum, NY over the past four years. Although designed for indoor use, the lightweight design of the PIDW was critical to the Light Infantry 10th Mountain Division's mission. Their Chief of Staff was introduced to the technology during these exercises, and in responding to a need for immediate operational deployment of his unit requested a PIDW be prepared and immediately shipped to Ft. Drum. The DataWall was to accompany his unit to an operational theater in Afghanistan.

An available DataWall was immediately transported from AFRL/IF's Collaborative Simulation Technology & Applications Branch at Wright-Patterson AFB, OH to Rome, NY. It was reassembled by the ADII team. Photographs were taken and an assembly/user's manual was developed. The latest incremental design changes were integrated and tested. New shipping containers were designed

and fabricated. The DataWall, assembly instruction manual, a field spares kit and the tools needed for assembly were delivered to the palletizing area at Ft. Drum on 4 December 2001 (28 hours after the request). The following week the operators that were scheduled to follow the equipment to the field came to Rome for eight hours of training. At that time they learned how to assemble, align and operate the equipment. The user’s manual was used during the training session and modified based on trainee feedback. The final version of the manual was delivered in electronic form the following day. This PIDW was used in theater for nearly nine months as a C2 display for daily update briefings from the various groups within the Division as well as to display live feeds from Intelligence, Surveillance, and Reconnaissance assets. An additional DataWall was requested with a three month lead time for delivery. The 2nd system was delivered on 28 February 2002 (a day earlier than promised) and was used in the Division Main HQ Emergency Operations Center (EOC) at Ft. Drum.

5.2.1 Lessons Learned

The system that was deployed to operational theater returned to AFRL/IF March 2003 and provided some valuable insight into further improvements. The shock-mount rack was not integrated at the time these systems were delivered which now greatly simplifies the assembly process and drastically reduces the number of shipping containers required for deployment. The PIDW was never designed to withstand harsh field conditions, which is how it was used while deployed to Afghanistan. Since the COTS electronic components have standard rack-mount chassis with standard ventilation slots and fans, exposure to dust posed a substantial problem. No equipment failed, but when AFRL/IF had the system returned to our laboratory for testing, evaluation, and minor frame repairs, all equipment showed evidence of substantial exposure to dust. The projectors, which are not designed to operate continuously, sustained the most exposure to dust and at times operated erratically. All internals were professionally cleaned for safety and to ensure proper operation. Components designed for harsh environments are currently being evaluated and methods to reduce exposure are being considered for future rugged DataWall frame designs.

Another area of interest for this type of field use of the DataWall is the rapid deployment and set up of the system. Minimizing the amount of disassembly, deployable footprint, and reassembly are paramount. Achieving seamless boundaries without loss of resolution is also important. However, in situations where rapid deployment and setup is critical, employing a blending and alignment algorithm could speed up the process and allow operators to concentrate on other tasks.

The DataWall is well suited for small collaborative cells and the way the 10th Mountain Division (Figure 27) employs it illustrates this point best. It is used to

present update briefings from the various groups within the Division as well as displaying live feeds from Intelligence, Surveillance, and Reconnaissance (ISR) assets.

Unfortunately it is still difficult to break most operators from the common mindset of seeing the DataWall as simply a set of three independent video projectors to display three sources of information at a time. For many, how a meta-desktop can be effectively used for data management is a difficult concept to grasp. Using the three projectors with three independent sources is still the most common mode of operation. AFRL/IF continues to work with them so that they can truly benefit from what the DataWall can provide and in return provide field experience feedback to guide our future research.

Figure 27 Portable DataWalls at Ft Drum NY

5.2.2 Impact and Current Status

Even before the PIDW redeployed from Afghanistan, a shock-mount rack system had already been incorporated which reduced its transportation footprint by 75 percent. Considerable improvements were made in set-up requirements which have reduced set-up time from about four hours to one hour or less. A rugged PC that could withstand extreme temperatures and dusty environments is currently under investigation.

The relationship with Ft Drum personnel continued to ensure operation and maintenance procedures were current. The system that was deployed overseas and returned from duty in March 2003 was repaired and the most current system upgrades integrated. After which the system was returned to Ft Drum to resume its duties. The status of both systems owned by the 10th Mountain Division is unknown at this time because of recent and continuing personnel deployments.

5.3 Electronic Systems Center, Hanscom AFB MA

In May 2003 the latest version of the Collapsible Interactive DataWall (CIDW) was installed at the Electronics Systems Center (ESC) at Hanscom AFB MA to support a joint Global Concept of Operations Synchronization (GCS) effort among the Air Force Research Laboratory, Air Combat Command, Air Mobility Command, and ESC. The objective of GCS is to improve information sharing and interoperability between Combat Air Forces (CAF) and Mobility Air Forces (MAF) mission planning and execution systems for improved velocity, efficiency, safety, and mission success. The CIDW is a key system in the architecture established for the demonstration because of its ability to bring distributed C2 applications into a single, interactive large display. Some of these applications include the Global Air Mobility Advanced Technology (GAMAT) as well as the Integrated Management Technology (IMT). As a result of the success of the preliminary experimentation, the system was purchased by ESC July 2003.

5.3.1 Lessons Learned

The CIDW has played a central role to GCS because it brought new capabilities and efficiencies in data processing, flow, and visualization. It also provided that common situational awareness environment where decision-makers can quickly identify problems and be proactive in solving potential ones. In concert with previous users of the PIDW and CIDW, there have been some concerns about the interaction with the data while using the laser pointer. Feedback provided by the users point to the difficulty in correctly aligning the cameras. Although the calibration routine and implementation of the laser interaction is now very accurate, proper alignment of the cameras is essential.

Figure 28 Collapsible Interactive DataWall at ESC

Portability and transportation have also been mentioned as problems. GCS has been demonstrated to various audiences in places that range from the Pentagon to large convention halls. The users have experienced difficulty in dealing with

the weight and size especially when large trucks and forklifts are not available. When packaged for transportation, the CIDW weighs approximately 1100 pounds. Set-up continues to be a key concern for users. A significant amount of visual systems technology and computing expertise have been cited as requirements to set it up correctly.

5.3.2 Impact and Current Status

Although manual alignment of projectors is a time-consuming process, there is no loss of resolution which is a major advantage; especially with certain applications. The recent upgrade to the CIDW projector mounts that provides six degrees of adjustment enables a user to manually and precisely align the projectors in significantly less time.

A solution to aligning the cameras employed for the laser pointer interaction has not been fully realized. The initial approach has been improvements to the camera calibration process that is significantly more simplified and less critical of misaligned camera positions to a certain degree. Ultimately, an automatic process where the typical user does not have a direct influence on the optimization of the camera position needs to be developed.

The system at ESC has been upgraded with the most current improvements including the new projector mounting and alignment system, and the lightweight integrated shipping container.

5.4 Northeast Air Defense Sector

In the Spring of 2002 personnel from the Air National Guard’s Northeast Air Defense Sector (NEADS) approached the ADII team for advice on upgrades to their large-screen situational display system in their main operations center. NEADS mission is to provide Total Force Air Defense and threat warning to North America through readiness, detection and identification, and if necessary, force application. For several months, our team worked very closely with NEADS to integrate a large-screen display, based on DataWall technology, designed specifically for their facility, budget, and demanding around-the-clock operational needs. This in turn has provided the foundation for potential integration of other Information Directorate Situation Awareness (SA) tools and techniques that might apply to the NEADS mission.

5.4.1 Requirements

The display system to be replaced consisted of five LCD-based front projectors each at a resolution of 1024 x 768 pixels displayed on five separate 6' x 4' screens approximately 10' off the ground. The problems the NEADS staff was experiencing with the configuration included overheating and subsequent permanent damage to their projectors from excessive use. The projectors were also not mounted to any permanent fixture that caused drastic geometry distortions to the projected images as a result of the inability to position the projectors at the correct pitch relative to the screen. The screens were mounted at a slight forward pitch to compensate to a certain extent, but still produced a less than optimal view for operators at an elevated position at the back of the room in the Battlecab (BC).

The new display had to be designed for effective viewing by operators on the main floor as well as from the elevated position of the BC. The system needed to operate around the clock without fail 24-hours/day, 7-days/week. Input devices needed to be effective from the BC primarily, with a certain degree of interaction if possible from the Ops floor. The budget for new equipment was extremely limited.

5.4.2 System Description and Installation

One element for consideration in the new system design was the physical characteristics of the facility. The unconventional architectural elements of the room such as the extremely high curved ceiling and the shear size of the room at approximately 50' x 50' posed significant challenges. The installation of the system also had to be accomplished with no disruption to ongoing 24-hour operations.

It was primarily cost and space considerations that led to a large front projection approach. The dim lighting conditions were also beneficial to this approach. The tall ceiling ensured adequate height for mounting the screen and projectors above operators' heads that might otherwise cast shadows on the screen.

A single 30' x 8' front projection screen was mounted as high as the arched ceiling would allow; approximately 7½' off the ground. Three LCD-based projectors each with a resolution of 1280 x 1024 pixels, with long-throw lenses were mounted to permanent, but adjustable fixtures above the BC. The mounts allowed mechanical adjustment to the projectors to create a seamless image across the entire display screen. The projectors selected had the desired resolution and lenses available with the correct focal length for the throw distance and image size. The need for around-the-clock operation necessitated an additional bank of three projectors be incorporated into the design to take half of

the 24-hours/day, 7-days/week operational load at six-hour intervals. It also provides redundancy in the event of projector(s) failure. The projectors also had a built-in motorized horizontal and vertical lens shift and programmable timers. The lens shift feature allowed the projector pairs to be mounted next to each other and their respective images shifted horizontally to the same area of the display screen. When either was powered on it would properly align with the image next to it. The built in timers allowed each projector to be programmed with its allotted duty cycle. Days of the week and six-hour operation times to power on and off could be set. The six projector layout was also specifically designed to allow uninterrupted display functionality during projector or lamp replacement (Figure 29).

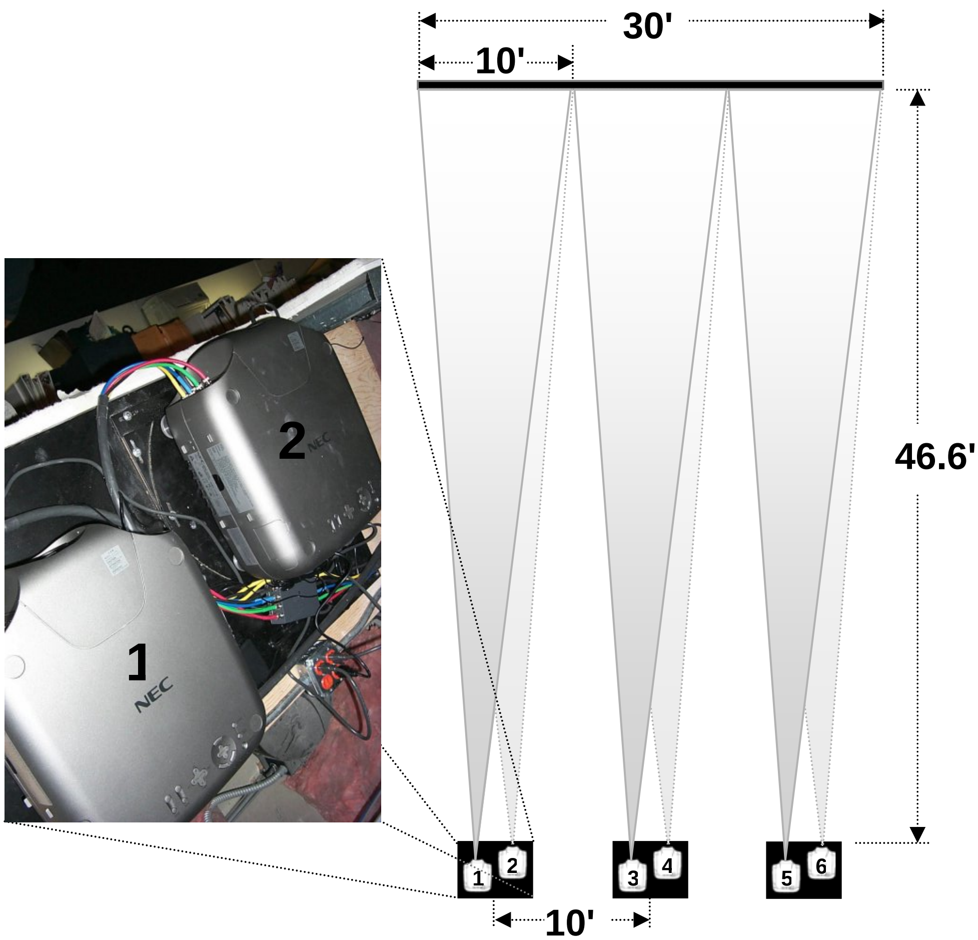


Figure 29 NEADS Projector Configuration

A single PC server configured with three video cards drives the display. Conventional keyboard and mouse in front of a three-screen display console allows interaction with applications running on the system in the BC. Wireless RF

mice with 100' range can also be used inside the BC or anywhere on the Ops floor. The entire installation was completed November 2002.

The technology advanced was the development and installation of a DataWall in an operational command and control environment on a much larger scale than what has been previously accomplished in the lab. One designed to be economical, with redundancy to ensure minimum downtime, and with effective modes of input for operators.

5.4.3 Lessons Learned

Although the system remained operational 24 hours/ day, 7 days/week for more than 2 years they did experience some degree of failures. At the time of the installation display devices designed for around-the-clock operations were extremely limited, very costly, and would have required significant construction of a support structure to install a system of comparable size and resolution. There were no commercially available projectors that could operate for such extended periods of time without eventual image degradation and would be covered by the factory warranties if they failed. LCD-based projectors require very bright lamps with subsequent heat that eventually started to degrade the color balance of the projected images due to damage to the LCDs. The six hour operating intervals helped, but the 12 hour/day total duty cycle for each projector was still too taxing. The projected images did degrade over time, but were always usable and never completely failed. Spare projectors were purchased and installed so that the damaged projectors could be repaired by the vendor.

There were also issues with the 3-output DataWall server that was installed to drive the display. It was later determined that three input/output sources was not sufficient. The noise of the DataWall server fans was also an issue and could not be placed in a location where operations were being run. However, it was important for the equipment to be placed next to a user in order to manipulate the input/output signals.

Digital Light Processing™ (DLP®) technology which is becoming ever more prevalent in the consumer and professional display community has emerged as the de facto standard for control room 24/7 operational environments. They generate significantly less heat and because the technology is reflective rather than transmissive, has a lower failure rate than an LCD-based system. Manufacturers are offering DLP®-based products that are rated and warrantied for 24/7 operation. At the time of the NEADS installation products available with DLP® technology were very limited, expensive, only in smaller stackable cube displays, and with limited resolution. The budget set for the project could not afford such an installation.

5.4.4 Impact and Current Status

In August of 2005, NEADS hired a contractor to upgrade a majority of the DataWall system that was problematic, which included the server and projectors that the ADII team initially installed with a new Audio/Visual (A/V) system.

The projectors were replaced with Panasonic model PT-D7600U that are 3-chip DLP projectors with a liquid-cooled light engine and sealed optics system offering longer projector life. Although they are not specifically rated for 24/7 operations, the technology characteristics of DLPs, along with the sealed-liquid-cooling system, and operating at a lower brightness setting should prove to be a more reliable system for the environment.

The DataWall server was replaced with an AMX Master Controller model NI 3000+ and Extron Matrix Switcher, which gives the ability to have 32-inputs/outputs for the system. They also purchased two touch-screen control panels that can remotely control the inputs and outputs of the system.

They also installed eight 42″ LCD screens and four 60″ LCD screens to give more flexibility in displaying operational information. This gives the Ops personnel more display capability.

Their display needs, budget, and display technology changed dramatically from the time the original installation was accomplished. It is encouraging that they are now able get the customer support they need that we are not adequately staffed to provide and are able to take advantage of the latest display technology better suited for their high tempo 24/7 C2 environment. It is a little disappointing that they have in certain respects taken a few steps backward in terms of managing the display space by reverting to a conventional video switching system. This fact does reinforce the requirement to further improve the usability of the DataWall, however.

5.5 Air Force Institute of Technology, Wright-Patterson AFB OH

The Air Force Institute of Technology (AFIT) and Wright State University (WSU) received a grant from the Ohio Board of Regents to develop a collaborative virtual environment for exploring HCI and visualization techniques. AFIT's portion of this grant involved the acquisition of a display system for command and control visualization. Having seen the AFRL/IF developed Portable DataWall, AFIT sought to acquire one of their own to have a configuration that is common to AFRL and other AF organizations to better facilitate their research in support of these organizations. Despite AFIT's limited budget to purchase a display system, AFRL/IF agreed to provide a slightly used Portable DataWall at a

significantly reduced cost in exchange for some research in support of the DataWall project.

A CRADA was established among AFRL/IF, AFIT, and Wright State University (WSU). The objective of the agreement is to share HCI, visualization, and display system technology under development at AFRL/IF, AFIT, and WSU. AFRL/IF delivered and installed a Portable Interactive DataWall at AFIT on 30 March 2004. WSU, using funds from the grant, partially reimbursed AFRL/IF for the cost of the DataWall. AFIT and WSU will research HCI and visualization techniques using the DataWall, sharing meaningful results with AFRL/IF.

Anticipated benefits to AFRL/IF from this agreement include improvements to the DataWall's HCI capabilities either from evaluation feedback or new software developed by AFIT. In addition, AFIT will deliver C2 visualization software to AFRL/IF that has been successfully installed on the DataWall and determined to be useful to AFRL/IF and further show the utility of a large interactive display in a C2 environment. It was also an opportunity for someone to make use of what we considered obsolete equipment in return for some funds to purchase more current equipment to further the DataWall in-house development.

5.5.1 Impact and Current Status

The DataWall installation at AFIT is still operational and includes the addition of an InterSense IS-900 virtual reality controller. Since arriving at AFIT, the DataWall has been used to demonstrate and interact with two different UAV swarm models, and also in the initial interfacing with the InterSense controller.

Some of the usage hurdles that have been identified include no mechanism for multiple users to interact with the DataWall and information represented simultaneously. Providing the capability for multiple users to simultaneously interact with the display is an ongoing research project that has been highly successful since the initial DataWall installation at AFIT, but is not a capability currently installed at their site. It was not part of the original agreement so there were no plans to provide it. Their needs are slightly different, however, in that they would like multiple users to be able to interact within a single application rather than multiple applications as our current system has been designed. In most instances this is not very useful in our opinion so would most likely require custom applications to support the capability. There are currently no plans to do so, but have recognized there is a need, albeit limited, with potential for future development.

Also a human caused distance/accuracy problem was identified, in that it is extremely difficult to use the laser pointer accurately at distances where the entire wall is in view or larger. With the additional interface to the InterSense

controller being developed, they anticipate that this will become more manageable but may also open up a large number of additional technical hurdles associated with distance and perspective. The problem has been a continuing criticism we hope to be able to solve or ease at some point in the near future.

6 Future Research

6.1 DataWall Display Enhancements

The importance of an expanded viewable space and increased image resolution, are imperatively considered in the designs of the next generation Interactive DataWall, and other display system development. Because of the often close screen interaction with these displays, a pixel density that matches the visual acuity of the human eye at these close distances is desired. As COTS display technology improves in both the direct-view and projector product markets they will be evaluated and potentially integrated into our experimental systems. The recent display technology push to support the emerging high-definition television (HDTV) standard has resulted in a much wider selection of products available that meet our display design requirements. Among the planned enhancements include incorporating multiple HD resolution devices (1920x1080) and in larger matrix configurations.

6.2 Touch Screen Integration Completion

Touch screen technology has improved significantly over the past few years particularly with respect to scalability and image quality preservation. The benefit of adding touch interaction to the IDW is being explored. Touch technology would not be a replacement for the laser pointer interaction but rather another enhancement by providing the users with another mode of input.

Integration of a touch screen capability for the DataWall is well underway with the CIDW frame redesign, fabrication and delivery of a prototype system complete. A screen design will be finalized and integrated into the system shortly. Confidence is high in the ability to scale touch screen technology to large multi-projector displays with recent advances in the state-of-the-art. The feasibility of utilizing a common set of cameras to track lasers and touch will also be investigated.

Based on the success of the integration of touch interaction into the CIDW and human factors evaluations for this type of interaction on very large displays will dictate the degree to which it will be integrated into future portable and built-in DataWall systems.

6.3 Gesture Recognition

Gesture recognition geared for a large screen display is being explored and developed through a research program with Howard University. The central approach for the feasibility of the program will utilize a differentiating technique to initially identify pointers via image triangulation methods for accurate positioning and tracking of pointers, and the usage of cutting edge high resolution cameras. Methods for multiple pointers and a working system for recognizing a variety of hand gestures will be developed during the course of the research program's duration.

As an initial stage for evaluating the feasibility of tracking pointers, a simulation for pointer detection in 3-dimensional space for validating the accuracy and performance of the algorithm was conducted. Preliminary results hypothetically revealed significant figures for tracking. The exploration and vision of such capability for an extensively scaled display environment leads to direct applicability for multiple participants to interact with a large screen display in a Command and Control setting with minimal or no obstruction.

6.4 Portable Display Modules (PDMs)

One enhanced capability expressed by users of the Portable DataWall systems is a desire for a larger display system that is still portable. Although the 9′ width has proven adequate, the height of 29″ is limiting. In order to keep the operational depth from increasing and avoiding the use of folded optics, the approach planned is to tile projectors vertically as well as horizontally. A preliminary design for a Portable Display Module (PDM) has been conceptualized that incorporates two projectors stacked vertically and a screen 36″W x 54″H. The screen will be a commercially available near frameless system that will allow multiple PDMs to be linked together to build any *n* x 2 tiled display that is 54″ high and virtually seamless (Figure 30).

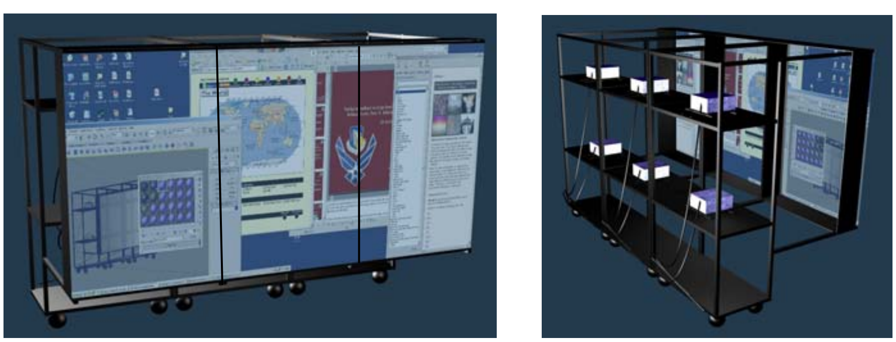


Figure 30 Portable Display Module Concept (3 module example)

6.5 *Automatic Projector and Camera Alignment*

Developing and incorporating an automatic projector and camera alignment system to help speed the set-up of the IDW is being investigated. It will be of particular value to the portable systems being developed that require realignment after each deployment. The typical user of the IDW is not an Audio/Visual expert and it is unrealistic in most instances to expect this user to arrive at a nearly seamless alignment of the projectors. A very daunting task will be to develop an electromechanical projector mount that uses optical sensors to determine alignment accuracy and automatically correct the projector position. The intent is to still rely on physical repositioning of the projectors to correct the image geometry rather than digitally. Edge blending and image warping techniques have been avoided in the past to preserve the full resolution of the display. However, it will be investigated for the final fine-tune adjustment to further improve image quality and simplify set-up for inexperienced operators. Furthermore, it is unrealistic to expect a novice user to tackle every possible scenario in which the cameras are the cause of any laser tracking problems. Methods for simplifying camera positioning and improvements to the calibration process are also being investigated.

7 Conclusions

The Interactive DataWall in its various stages of development and configurations has been the all encapsulating operational product that has resulted from all of the ADII display and HCI research. It has been demonstrated to a number of visitors at AFRL/IF at Rome Research Site. The Deployable and Portable/Collapsible Interactive DataWalls have been deployed and demonstrated at a number of off-site conferences and military exercises. Several Portable DataWalls have been transitioned to customers outside our research facility. They have been extremely well received, so the ADII team is confident that research efforts are headed in the right direction for next generation C2 systems. Although a considerable amount of research and development remains, extremely capable systems have been created, integrating a significant amount of commercially available hardware and software. Its evolution has been driven by warfighter requirements and valuable field experiences.

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